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RECENT ADVANCES IN THE MANUFACTURE OF HIGH-GRADE BOILER AND PIPE MATERIAL.

It appears that, what in the mechanical world's progress may be called suddenly, marine engineers have decided that high pressures at sea are no longer to be "downed" by reason of mechanical difficulties in handling them. Thus at almost the stroke of the bell the cumbrous Scotch boiler is swept into the category of the old style, and the lighter water-tube boiler, with its practically limitless possibilities in way of providing steam at any desired pressure and within the shortest possible time, comes in with an initial jump of 100 pounds per square inch over the upper limit of our recent custom. That we should now design for 250 pounds in the boilers to be reduced to 200 pounds at the engine does not appear to be half as much of an innovation as did the use of steam at 100 pounds when our first compound engines came into use twenty years ago, and prior to which the gage needle of our navy boilers seldom passed the 50 mark.

Increase of pressures brings properly a demand for the very best material with which to construct the boilers. *Reliability* is

the desideratum, as no element of the construction can be defective without imperiling the whole, and with it jeopardizing the lives of those in charge of the plant.

Of late years, and indeed ever since mild steel set out to replace wrought iron, there has been continuous and rapid progress in the art of manufacturing this material, until any desired quality can be uniformly produced by the most careful makers. Undoubtedly the Government inspections and the tests that have been imposed by the Bureau of Steam Engineering, for all material before acceptance, has wonderfully assisted in the advances in the art of steel producing in this country. It has stimulated a beneficial rivalry that has resulted in almost entirely eliminating the elements of unreliability and non-uniformity from the forged steel of to-day. And even with cast steel there is little left to find fault with.

Comparatively recently nickel steel, which has for years been extensively used in armor, has been attracting considerable notice as being most admirably adapted to parts of boiler work, especially to bracing and rivets, and through the patriotic interest of some of our manufacturers we have had tests made which are as valuable as they are interesting. One of these series was published in the last issue of the JOURNAL from notes by Mr. Manusel White, and referred to the excellence of nickel-steel rivets, which with a tensile strength of over 75,000 pounds per square inch, and an elastic limit of over 40,000 pounds, enable us to use a much smaller rivet, cutting away much less of the original plate for the holes. As Mr. White noted, they have quite a fair range of heat at which they can be safely driven, the precaution being not to go above a bright cherry red. These rivets proved to be tougher and freer from the brittleness of heads formed by sledge and cup set, which sometimes appears with common steel rivets.

As to nickel-steel for boiler braces and rods, there is a certain superiority quite as definite as with the rivets. In figure 1 a test piece of this material is shown leaning over the section of pipe, the ends showing the fracture and reduction due to breaking it in the testing machine. This material had the following charac-

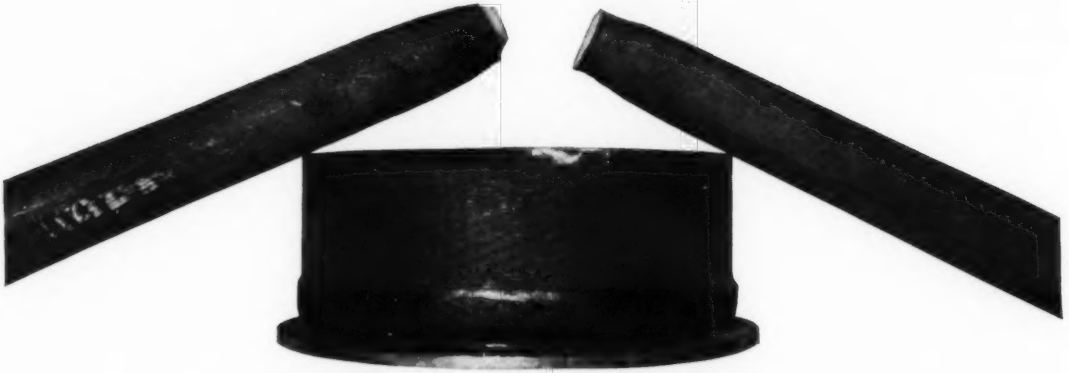

FIG. 1.

teristics, chemical composition: Carbon, .23; sulphur, .017; manganese, .61; nickel, 3.22, and phosphorus, .021.

Its average tensile strength is over 80,000 pounds per square inch, with elastic limit of over 55,000 pounds per square inch, and an elongation of more than 23 per cent. in 8 inches, the accompanying reduction of area being 55 per cent. This material is very uniform and exceedingly reliable, being as tough as steel can be made. When subjected to a drop test it tears a grain at a time, holding together during many blows after fracture begins. In several cases where bars of this composition *four* inches diameter have been tested by dropping a weight of 1,640 pounds upon them from a height of forty-four feet, the bars being supported at their ends only, and after each drop the bars being turned over to put the convex part of the resultant bend always uppermost, it required forty blows of this nature *before fracture begun*, and forty additional blows to complete the break.

Comparing the specifications of even ten years ago, shows the care with which the inspection work has been supervised, and the safeguards with which it has been surrounded to the almost certain exclusion from use of anything but the very best material. Take, for instance, the specifications for steel for the *Maine's* boilers in 1888.

BOILER PLATES.

"24. Boiler plates, shapes, braces and rivets must not show more than .03 of 1 per cent. of phosphorus; all other steel material not to show more than .06 of 1 per cent. of phosphorus.

"26. One tensile test piece shall be cut from each plate as rolled for boilers, either longitudinally or transversely, as directed by the Inspector, and one piece to be used as a bending piece.

"27. *Tensile tests of shell plates.*—Transverse specimens must show a tensile strength between 58,000 and 67,000 pounds, with an elongation of at least 22 per cent. Longitudinal specimens must show a tensile strength between 58,000 and 67,000 pounds, with an elongation of at least 25 per cent. The elastic limit must be at least 32,000 pounds per square inch.

"28. *Tensile tests of furnace and flange plates.*—Test pieces

must show a tensile strength between 50,000 and 58,000 pounds, with an elongation of 26 per cent. either longitudinally or transversely.

"29. *Cold-bending test.*—One piece to be cut from each shell plate as finished at the rolls for cold-bending test, which must bend over flat on itself without sign of fracture.

"30. *Quenching test.*—One piece shall be cut from each furnace or flange plate as finished at the rolls for quenching test, and after heating to a cherry red, plunged into water at a temperature of 82° F. Thus prepared, it must be possible to bend the piece so that it shall be doubled round a curve of which the diameter is not more than one and a half times the thickness of the piece tested, without showing any cracks. The ends of the pieces must be parallel after bending. Quenching and cold-bending pieces must not have their sheared or planed sides rounded off, the only treatment permitted being taking off the sharpness of the edges with a fine file.

" 31. *Surface inspection.*—Plates and shapes must be free from slag, foreign substances, brittleness, laminations, sand or scale marks, scabs, snakes, pits and surface defects generally. Shapes must also be free from defective sections, shaded back, grooved fillets, &c.

" 32. *Shearing.*—Boiler plates $\frac{3}{16}$ of an inch thick and over shall not be sheared closer to finished dimensions than once the thickness of the plate at each end and one-half the thickness of plate along each side.

TESTS FOR BOILER RIVETS.

" 33. Steel for rivets must be made by either the ordinary open-hearth or Clapp-Griffith process.

" 34. Each ton of rivets from the same heat or blow shall constitute a lot. Four specimens for tensile tests shall be cut from the bars from which the lot of rivets is made.

" 35. *Tensile tests.*—The rivets to be driven by power shall be from 58,000 to 67,000 pounds tensile strength, with an elongation of not less than 26 per cent.; and those to be driven by hand shall have a tensile strength of from 50,000 to 58,000 pounds, with an elongation of not less than 30 per cent.

"36. *Hammer test.*—From each lot twelve rivets are to be taken at random and submitted to the following tests:

"37. Four rivets to be flattened out cold under the hammer to a thickness of one-half the diameter without showing cracks or flaws.

"38. Four rivets to be flattened out hot under the hammer to a thickness of one-third the diameter without showing cracks or flaws—the heat to be the working heat when driven.

"39. Four rivets to be bent cold into the form of a hook with parallel sides without showing cracks or flaws.

MATERIAL FOR STAY-RODS AND BRACES.

"40. Two tons of material for boiler braces, from the same heat, shall constitute a lot from which one tensile test piece shall be taken.

"41. *Tensile test.*—Bracing coming into contact with the fire to have a tensile strength of from 50,000 to 58,000 pounds, and an elongation of not less than 26 per cent. Other bracing to have a tensile strength of not less than 65,000 pounds and an elongation of not less than 24 per cent.

"42. *Bending test.*—Bars one-half ($\frac{1}{2}$) inch thick, cut from the bracing coming into contact with the fire must stand bending double to an inner diameter of one and one-half ($1\frac{1}{2}$) inches after quenching in water at a temperature of 82° F., from a cherry-red heat, without showing cracks or flaws. Similar pieces cut from the other bracing must stand cold-bending double to an inner diameter of $1\frac{1}{2}$ inches."

And then compare this with the specifications for inspection of boiler material in 1898, for torpedo boats, destroyers, monitors and battleships now under construction.

BOILER PLATE. (CLASS A.)

"1. The inspection must conform to the 'General Instructions' for the inspection of material coming under the cognizance of the Bureau of Steam Engineering.

"2. The failure of a large proportion of the material inspected to stand the specified tests in a satisfactory manner will render the whole delivery liable to rejection.

"3. *Kind of material.*—Steel for boiler plates shall be made by the open-hearth process, and not show more than thirty-five one-thousandths ($\frac{35}{1000}$) of one (1) per centum of phosphorus nor more than three one-hundredths ($\frac{3}{100}$) of one (1) per centum of sulphur, and be of the best composition in other respects.

"4. *Test specimens.*—One tensile-test piece, taken longitudinally, and one bending test piece, taken transversely, shall be cut from each plate as rolled for boilers, as directed by the Naval Inspector. The cold-bending pieces must not have their sheared nor planed sides rounded off, but the sharpness of the edges may be taken off with a fine file.

"5. *Tensile tests of Class A No. 1 Plates.*—Test specimens must show a tensile strength between 74,000 and 82,000 pounds per square inch, with an elastic limit of 40,000 pounds per square inch, and an elongation of at least twenty-one (21) per centum in eight (8) inches.

"6. *Tensile tests of Class A No. 2 Plates.*—Test specimens must show a tensile strength between 66,000 and 74,000 pounds per square inch, with an elastic limit of at least 32,000 pounds per square inch, and an elongation of at least twenty-three (23) per centum in eight (8) inches.

"7. *Tensile tests of Class A No. 3 Plates.*—Test specimens must show a tensile strength between 60,000 and 66,000 pounds per square inch, with an elastic limit of at least 36,000 pounds per square inch, and an elongation of at least twenty-five (25) per centum in eight (8) inches.

"8. *Cold-bending test.*—One specimen, cut from each Class A No. 1 and Class A No. 2 Plate, as finished at the rolls for cold-bending test, shall bend round a curve the diameter of which is equal to the thickness of the plate tested till the sides of the specimen are parallel, without signs of fracture on the outside of the bent portion.

"9. *Cold-bending tests.*—One specimen, cut from each Class A No. 3 Plate, shall bend flat on itself without signs of fracture on the outside of the bent portion.

"10. *Inspection for surface and other defects.*—Plates must be free from slag, foreign substances, brittleness, laminations, hard

spots, injurious sand or scale marks, scabs, snakes, and injurious defects generally.

"11. *Shearing.*—Boiler plates, thirteen-sixteenths ($\frac{13}{16}$) of an inch thick and over, shall not be sheared closer to finished dimensions than once the thickness of the plate along each end, and one-half the thickness of the plate along each side. This allowance shall be made by the contractor on his order, and the manufacturer shall shear to ordered dimensions.

"12. *Weight and gage.*—Contractors shall enter on their orders to manufacturers both weight per square foot and gage of plates. Plates shall not vary from the specified weight more than the following amounts: Two (2) per centum below and seven (7) per centum above for plates more than one hundred and ten (110) inches wide; two (2) per centum below and six (6) per centum above for plates between one hundred (100) and one hundred and ten (110) inches wide; two (2) per centum below and five (5) per centum above for plates between eighty (80) and one hundred (100) inches wide; two (2) per centum below and four (4) per centum above for plates between sixty (60) and eighty (80) inches wide; and two (2) per centum below and three (3) per centum above for plates less than sixty (60) inches wide.

"13. *Gage.*—No plate must, at any point, fall below the specified thickness more than the following amounts: Six one-hundredths ($\frac{6}{100}$) of an inch for plates more than one hundred and ten (110) inches wide; five one-hundredths ($\frac{5}{100}$) of an inch for plates between one hundred (100) and one hundred and ten (110) inches wide; four one-hundredths ($\frac{4}{100}$) of an inch for plates between eighty (80) and one hundred (100) inches wide; three one-hundredths ($\frac{3}{100}$) of an inch for plates between sixty (60) and eighty (80) inches wide; and two one-hundredths ($\frac{2}{100}$) of an inch for plates less than sixty (60) inches wide.

"14. *Oil tempering and annealing.*—It is left optional with the manufacturers to oil temper and anneal Class A No. 1 Plates of a thickness greater than one (1) inch, in order to get the requirements of these specifications; but the oil tempering and annealing must be done before the plate is submitted to the Naval Inspector for tests.

"15. NOTE.—The Class A No. 1 and Class A No. 2 Plates must be taken from the tables as soon as finished at the rolls and covered with dry sand or ashes in order that they may cool slowly and evenly, in case they are not regularly annealed in an annealing furnace."

"BOILER BRACING. (CLASS A.)

"3. *Kind of material.*—Steel for stay bolts and braces shall be made by the open-hearth process, shall not show more than thirty-five one-thousandths ($\frac{35}{1000}$) of one (1) per centum of phosphorus, or more than three one-hundredths ($\frac{3}{100}$) of one (1) per centum of sulphur, and shall be of the best composition in other respects. The drillings for chemical analysis shall be taken from the same objects as the tensile-test pieces.

"4. One ton of material for boiler braces, from the same heat, shall constitute a lot from which two tensile and one cold-bending test specimens shall be taken, each from a different object.

"5. *Treatment.*—All material for boiler bracing shall be annealed as a final process.

"6. *Tensile tests of Class A No. 1 Bracing.*—Test specimens must show a tensile strength of at least 74,000 pounds per square inch, with an elastic limit of at least 40,000 pounds per square inch, and an elongation of at least twenty-two (22) per centum in eight (8) inches, or twenty-six (26) per centum in two (2) inches, in case 8-inch specimens can not be secured.

"7. *Tensile tests of Class A No. 2 Bracing.*—Test specimens must show a tensile strength of at least 66,000 pounds per square inch, with an elastic limit of at least 36,000 pounds per square inch, and an elongation of at least twenty-four (24) per centum in eight (8) inches, or twenty-eight (28) per centum in two (2) inches, in case 8-inch specimens can not be secured.

"8. *Tensile tests of Class A No. 3 Bracing.*—Test specimens must show a tensile strength of at least 60,000 pounds per square inch, with an elastic limit of at least 32,000 pounds per square inch, and an elongation of at least twenty-six (26) per centum in eight (8) inches, or thirty (30) per centum in two (2) inches, in case 8-inch specimens can not be secured.

"9. *Cold-bending test.*—One bar, one-half ($\frac{1}{2}$) inch thick, cut from each lot of Class A No. 1 bracing shall stand cold bending double to an inner diameter of one (1) inch, the ends of the piece being brought parallel, without showing signs of fracture on the outside of the bent portion.

"10. *Cold-bending test.*—One bar, one-half ($\frac{1}{2}$) inch thick, cut from each lot of Class A No. 2 bracing shall stand cold bending double to an inner diameter of one-half ($\frac{1}{2}$) inch, the ends of the piece being brought parallel, without showing signs of fracture on the outside of the bent portion.

"11. *Cold-bending test.*—One bar, one-half ($\frac{1}{2}$) inch thick, cut from each lot of Class A No. 3 bracing shall stand cold bending flat on itself, the ends of the piece being brought parallel, without showing signs of fracture on the outside of the bent portion.

"12. *Opening and closing tests.*—Angles, T bars, and other shapes, are to be subjected to the following additional tests: A piece cut from one bar in twenty shall be opened out flat while cold, without showing cracks or flaws; a piece cut from another bar in the same lot shall be closed down on itself until the two sides touch, without showing cracks or flaws.

"13. *Inspection for surface and other defects.*—Stay rods and bracing must be true to form, free from seams, hard spots, brittleness, injurious sand or scale marks, and injurious defects generally.

"14. Boiler plate used as boiler bracing shall be inspected as plate under the specifications for boiler plate of the class required by the machinery specifications.

"SPECIFICATIONS FOR RIVET RODS AND FINISHED RIVETS.

"3. *Kinds of material; High grade and Class A rivet round* shall be made by the open-hearth process; shall not show more than thirty-five thousandths of 1 per cent. of phosphorus, nor more than three-hundredths of 1 per cent. of sulphur; and shall be of the best composition in other respects. The drillings for chemical analysis shall be taken from the cold-bending test specimens.

" *Class B rivet rounds* may be made either by the open-hearth

or Bessemer process, and shall be used in all Class B material and may be used in other material if permitted by the Machinery Specifications.

TENSILE AND BENDING TESTS TAKEN FROM THE RIVET RODS.

(To be tested in the full size of the rods when possible.)

"4. *Test specimens.*—If the total weight of rods rolled from a heat amounts to more than six tons, then the Naval Inspector shall select, at random, six tensile-test pieces, three cold-bending test pieces, and three quenching-test pieces, each from a different rod. If the total weight of rods rolled from a heat amounts to less than six tons, then the Naval Inspector shall select, at random, one tensile, one cold-bending, and one quenching-test piece for each ton or part of ton, each from a different rod. If only one of these rods selected for test fails, the Naval Inspector shall select another rod from the same lot and put it through the same test as the one that failed; and if it is found satisfactory he shall pass the lot. The tensile test of sizes of rounds under five-eighths of an inch in diameter shall be made on rounds of five-eighths of an inch in diameter.

"5. *High-grade rivet rods*, of nickel steel, shall have from 75,000 to 85,000 pounds per square inch tensile strength, with an elastic limit of at least 40,000 pounds per square inch, and an elongation of at least 23 per cent. in eight inches.

"6. *Class A, rivet rods*, of open-hearth steel, shall have from 60,000 to 68,000 pounds per square inch tensile strength, with an elastic limit of at least 32,000 pounds per square inch, and an elongation of at least 26 per cent. in eight inches.

"7. *Class B, rivet rods*, of open-hearth or Bessemer steel shall have from 54,000 to 62,000 pounds per square inch tensile strength, with an elastic limit of at least 30,000 pounds per square inch, and an elongation of at least 29 per cent. in eight inches.

"8. *Cold-bending test.*—The specimen shall stand cold bending double to an inner diameter of one-half inch without showing cracks or flaws on the outside of the bent portion.

"9. *Quenching test.*—The specimen shall, after heating to a

dark cherry red, in daylight, be plunged into water of a temperature of 82° F., and shall then stand bending double to an inner diameter of one-half inch without showing cracks or flaws on the outside of the bent portion.

"HAMMER TESTS ON FINISHED RIVETS.

"10. *Hammer tests.*—For each ton in weight of finished rivets, made from the same heat, four rivets shall be selected, at random, by the Naval Inspector and submitted to the following tests:

"(*a*) One-half of these specimens of each size to be flattened out cold under the hammer to a thickness of one-half the original diameter of the part flattened without showing cracks or flaws.

"(*b*) One-half of these specimens of each size to be flattened out hot under the hammer to a thickness of one-third of the original diameter of the part flattened without showing cracks or flaws; the heat to be the ordinary working heat of rivets when driven.

"11. *Inspection for surface and other defects.*—Rivets shall be true to form, concentric, and free from injurious scale, fins, seams, and all other injurious defects."

SPECIFICATIONS FOR THE INSPECTION OF SEAMLESS COLD-DRAWN BOILER TUBES OF STEEL.

"1. The inspection must conform to the 'General Instructions for the Inspection of Material coming under the cognizance of the Bureau of Steam Engineering.'

"2. These tubes will be made of low-carbon mild steel, of the best composition for the purpose, and uniform in quality and grade. The Naval Inspector will take drillings for chemical analyses.

"3. The tubes will be inspected for surface defects after being straightened, but before being cut to length, and they must be free from rust, scale, sand marks, laminations, hard spots, checks, cracks, and injurious defects generally.

"4. The pointed end of the tubes will then be cut off, trimmed, and gaged, and each tube at the thinnest point must be up to

the gage ordered. The interior of each tube will be inspected at the same time, and any that are badly seamed or scratched in the drawing will be rejected.

"5. The tubes which have passed the above inspection will then be cut to the lengths ordered and gaged at the end last cut off, and each tube at the thinnest point must be up to the gage ordered. A sufficient number of test tubes, selected and stamped by the Naval Inspector, will be cut about four inches longer than ordered.

"6. If the tube ends are flanged, swedged down, swelled, upset, or reenforced, they will be inspected afterwards to see that no material damage has been done by this process.

"7. Each tube shall be subjected to 1,000 pounds internal hydrostatic pressure without showing weakness or defects.

"8. All tubes must be annealed in retorts or an approved furnace in which the flame from the fuel used in heating the annealing furnace does not strike the tubes. One or more of the stamped test tubes will be placed in the center of each retort or middle of each furnace charge, one for each twenty-five tubes or less. The charge of each retort or furnace will be numbered and kept separate until the tests are completed. The test tubes will be given the same number as the charge with which they are annealed, so that if it is found after testing that any lot is not soft enough, it may be reannealed.

"9. The annealed tubes will then be divided into lots of not more than one hundred each, and the Naval Inspector will subject four of the stamped test tubes belonging to each lot to the following tests:

"*a*. The end of one test tube must stand being flattened by hammering until the sides are brought parallel, with a curve on the insides at the ends not greater in diameter than twice the thickness of the metal in the tube without showing cracks or flaws.

"*b*. One test tube shall have a piece 1 inch long cut from the end, which must stand crushing in the direction of its axis, under a hammer, until shortened to $\frac{1}{2}$ inch without showing cracks or flaws.

"*c*. The end of one test tube, cold, shall have a smooth taper pin, taper 1½ inches to the foot, driven into it until the end of the piece stretches to 1⅛ times the original diameter, without showing cracks or flaws.

"*d*. The end of one test tube, heated to a bright cherry red, in daylight, shall have a smooth taper pin, taper 1½ inches to the foot, at a dull red heat, in daylight, driven into it until it stretches to 1⅛ times its original diameter.

"If any one of these tubes selected for test fails, that tube will be rejected, and the Inspector will select two extra tubes from the same lot and put them through the same test as the tube that failed, and both of these tubes must be found satisfactory in order that the lot may be passed. The failure to pass satisfactorily any of the tests marked *a*, *b*, *c*, *d* will reject the lot.

"10. Each tube will then be separately weighed and accepted up to 8 per cent. above the standard weight for the gage ordered. The standard weight for seamless drawn steel tubes will be 0.283 pound per cubic inch of material.

"Each tube will be stenciled with the name of the vessel for which intended, or with the number of the order.

"11. The failure of a large proportion of the tubes selected to stand any of the above specified tests in a satisfactory manner will render the whole delivery liable to rejection.

"12. All tubes rejected will be marked in such a manner as to prevent their being presented a second time for inspection.

"13. The tube inspector's "Identification Stamp" and the "U.S. Anchor Stamp" shall be put on the cases in which the tubes are shipped. If the tubes are shipped in box cars containing no other freight, the cars must be sealed and the above stamps put on with the seal, and, in this case, it will not be necessary to box or crate the tubes."

Boiler tubes, fittings and steam and water pipes are now, of course, subjected to the increased pressure, and are objects of as much concern regarding their trustworthiness and perfection as is the boiler proper. Steel is the material for these parts best adapted, and the sample section of pipe in Fig. 1 is a lap-welded seven-inch steel steam pipe for torpedo-boat work. The one-

inch sharp angle flange on the end of this pipe was turned cold without showing any cracks or flaws, and it was afterwards pened to represent the manner in which it would be necessary to treat the metal to put a full flange on it. The seamless-drawn steel piping stands this test even with less risk, as there is no danger in that case of faulty welds, which would surely be discovered in the severe treatment.

In the advances of seamless-drawn pipe making comes a novelty illustrated by Fig. 2, in which is shown the possibility of making both T's and crosses in this manner. As these are necessarily of the very highest grade steel, the advantages they possess over the bulkier and less reliable castings usual to such forms are obvious, and especially for the express type of boiler work where reduction of weight, provided it does not decrease strength or reduce longevity, is most desirable.

The last number of the JOURNAL alluded to the fine surfaces of the solid-drawn tubes. Recent discussions as to what is meant by "solid-drawn" have been published in several of the technical papers. With the Bureau of Steam Engineering the term implies only tubes drawn through dies, from the solid ingot and does not include lap-welded tubes drawn down. The latter may present as fine a surface but the very fact of the possibility of a weld being started by the process and yet undiscernable to the inspector, creates a doubt which is not consistent with the spirit of the specification.

Great improvements have been made in the method of obtaining excellence in the matter of pipe flanges for high pressures, and the results up to the present time have been not only highly satisfactory, but embrace features of novelty and interest as well. With the adoption of steel for high-pressure steam pipes came the necessity of making sure that defects should not develop in the flanges. Not only is the element of danger one to be thus guarded against, but also the issues of economy which are so seriously damaged by leaky joints. The flanges must be substantial, and heavy enough to permit of properly making and holding the junctions of sections and preserving the integrity of the system, and at the same time they must be as nearly a por-

FIG. 2.

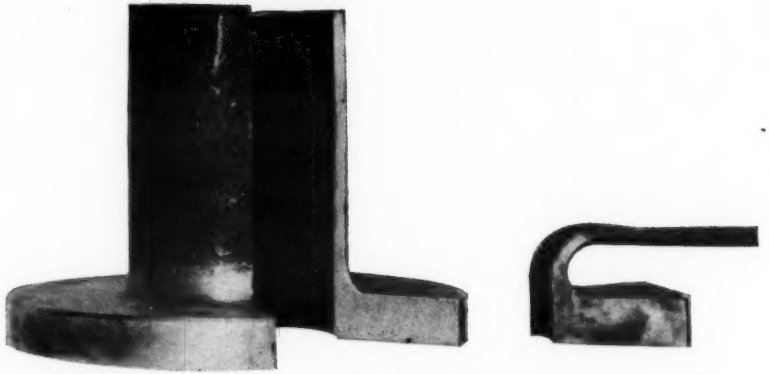

FIG. 3.

tion of the pipe itself as is possible to make it. Hence the superiority of a perfectly-welded flange over the old brazed and riveted flanges of our lower-pressure copper pipes, or the riveted and calked flanges of wrought-iron pipes. Fig. 3 shows how perfectly this work of welding flanges is now done; and it is applied equally readily to pipes of one inch and as high as thirty inches in diameter. Also there is no necessity of the metal of pipe and flange being alike, as an iron flange can be welded either to a steel or iron pipe. These flanges are cut from a solid plate.

The test here shown was made by cutting a section for a selected pipe as shown in the figure and bending the strips of pipe parallel to face of flange, the *bend* being *in the weld.* The perfection of the weld is thus clearly shown, and with a seamless-drawn pipe and a solid-cut flange there is little room to criticise the result in points of either solidity or finish.

The thickness of pipe desired in order to make the weld properly is given as follows:

Two-inch pipe should be No. 6 B.W.G. thick; 4-inch pipe should be No. 4 B.W.G. thick; 5 and 6-inch pipe should be $\frac{1}{4}$-inch thick; 8-inch pipe should be $\frac{5}{16}$-inch thick.

Pipes can be solid drawn up to 8 inches diameter.

In the matter of flanging, however, there has been produced a more remarkable result than the above with low-carbon steel of finest grade, following the lines of "*spinning*" the metal. This is shown by the three samples in Fig. 4 (frontispiece).

The piece in the middle represents a heavy "upset" two inches long on a No. 8 B.W.G. seamless-drawn boiler tube. The upset end was then swelled, cold, with a taper mandrel, and being placed in a special machine, resembling a lathe, was rapidly revolved, while a former was, by special hydraulic machinery, pressed steadily and powerfully against the expanded end until the metal was heated and spun into the general shape of a flange. It was necessary to cut only one-eighth inch from the edge of this flange to remove absolutely all indications of fraying or cracks, and then the flange end was trued up to give it the finished appearance shown in the two outside pieces in the figure.

A powerful machine is now under construction by which this character of work will be applied to pipes up to eight inches outside diameter, which includes all the sizes of steam and water pipe now used in torpedo boats and destroyers building for the Government.

A series of tests is now being made on these flanges, using high-grade nickel-steel bolts, to determine just what pressure the flanges will stand. The thickness of flange necessary for each size of piping will be practically determined, and each piece will be tested to rupture, to locate the weak points in the design.

A DISCUSSION OF PASSED ASSISTANT ENGINEER J. K. ROBISON'S PAPER ON "WATER-TUBE BOILERS A NECESSITY."*

Charles Ward.—No subject has, perhaps, had more consideration and discussion among marine engineers than that of the desirability of water-tube boilers. So much has been said and written upon them that one familiar with the subject would hesitate to write a paper presenting any new features. But Mr. Robison has taken quite an original view of the matter, and given us a very practical side of the question. He has utilized the practical experience with these boilers during the Spanish war, and set forth some very practical deductions which will be carefully considered in our future work and practice.

The very first deduction or assertion in the title of the paper, "Water-Tube Boilers a Necessity," is a source of gratification to those who, like myself, have been struggling for upwards of twenty years to secure the adoption of water-tube boilers for marine use. In connection with this assertion, we may also note that Commodore Melville, in his last annual report, thus expresses himself: "The demands upon the engineer for great power on small weight, in order to secure the higher speeds for all classes of vessels which are now common, have practically ruled out the cylindrical boiler."

In no department of science or branch of engineering has there been more progress than in marine engineering. Vessels designed and built only a very few years ago and still magnificent specimens of the art, would to-day be vastly improved by the application of principles which have evolved in the very few years just passed. The steam pressures of 250 and 300 pounds now considered a necessity in a battleship, would not have had serious consideration three or four years ago; yet to-day most of the

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navies of the world are formulating their plans on boiler pressures of 250 pounds and 300 pounds, which, of course, excludes the use of anything but water-tube boilers. So that the title of the paper seems entirely justified, though at first, at least to the old school, quite startling.

To one who has been laboring so long in this direction, it seems strange that the evolution should have been so slow. It is upwards of twenty years since we commenced building marine water-tube boilers. In the year 1882, we placed on a vessel in New York city a water-tube boiler having 85 square feet of grate and 3,000 square feet of heating surface, which was tested on board to 850 pounds hydraulic pressure. The engines, which were to use steam at 500 pounds, were, however, a failure, partly from bad design and partly from want of capital to correct the errors. The engines being condemned, it was decided to test the efficiency of the boiler, and if found satisfactory, to put in new machinery. I was accordingly called upon, in the summer of 1883, to demonstrate by actual test under forced draft and 250 pounds steam pressure, the capacity of this boiler, which had already been condemned by one of the most prominent engineering firms of New York. Mr. W. H. Rodman, then superintending engineer for Mr. John Roach, was called in on behalf of the owners of the vessel. Mr. Rodman reported, after the test, that the boiler had capacity to furnish more steam than the boat could utilize. The steam pressure at that day was more than engine builders cared to handle. At my suggestion, indorsed by Mr. Rodman, it was decided to put in a triple-expansion engine to use steam at 180 pounds to 200 pounds, if I remember rightly. The work was entrusted to the Bath Marine Iron Works, of Bath, Maine. The engine was designed, built and installed, with most satisfactory results, under the direction of Mr. Charles H. Hyde, thereby giving him the distinction of designing and building the first marine triple-expansion engine in America. This vessel was afterwards changed into a yacht, and is now named the "*Golden Rod*," and owned by Archibald Watt, Esq., ex-commodore of the American Yacht Club.

At that time 250 pounds of steam was considered out of the

question, but to-day, it is an established fact, with a very decided tendency upwards, and who will venture to say where it shall stop? With this change the water-tube boiler has truly become "a necessity." Their use in actual warfare has been tested and many new conditions and requirements developed during the late war, and we are fortunate in having their good qualities and defects so aptly portrayed by the author of the paper, who has pointed out many features to be considered in future designs.

Mr. Robison calls attention to the personnel. This is most important. You may as well be without ships as men to operate them. This applies not only to the men, but also to their qualifications. It is absolutely necessary to increase the personnel with the number of ships, and at the same time maintain its efficiency. An incompetent man is always a most expensive adjunct, and more emphatically so in a position of responsibility on one of our modern ships, which requires men above the average intelligence. I venture to say that much of the expense incurred in repairing the ships' machinery, made necessary by the war, would have been saved if well trained and efficient service could have been obtained. The efficiency of a war ship is as that of her crew. The time to prepare for war is during peace. It is just as necessary to have carefully-drilled firemen and water tenders as it is to have an efficient army. Who would think of taking green men into the field? Even in our own hurried preparation, the men were assembled, drilled in camp, broken to camp life and then moved in stages to the warmer climate and to active warfare. We have seen the best new boilers ruined by the carelessness and inefficiency of those in charge. We have in mind two boats engaged in the same service, in the same waters, having the same make of water-tube boilers, of the same material and design. One was ruined in two years, while the other was in use between five and six years without any repairs. In another case two large boats, each having four large water-tube boilers of the same design, manufacture and material,—the boilers of one boat needed few repairs, while the other was constantly out of order. After much censure being heaped upon

the boilers, it was found that changing a part of the crew from one boat to the other, changed the conditions.

Mr. Frank L. Dubosque, the efficient Assistant Superintendent of Floating Equipment of the Pennsylvania Railroad, thus expresses himself at a recent meeting of the Society of Naval Architects and Marine Engineers: "Water-tube boilers are a success, phenomenally so on a great many torpedo boats, and there is no reason why they should be made a failure on any one. I believe the failure of water-tube boilers on any boat is due to neglect, when the boilers are properly designed. We have had personal experience with five different types of water-tube boilers, four of which were of excellent design. On all four, what little trouble has been experienced has been clearly traceable to management. After some little experience, I can say safely that all four of these types are now being operated successfully by the most unskilled labor in the fireroom. Further than that, they are being operated from sixteen to eighteen hours every day of the week and week of the year."

Leaky condensers are a fruitful source of trouble with boilers. I recently saw an excellent water-tube boiler ruined from this cause. The spaces outside the tubes of the boiler were filled solid with salt. Upon investigation it was found that many of the condenser tubes had "crept out," and that an effort had been made to make the tube head tight by plastering with Portland cement. In this case, an inefficient or unprincipled man cost the owners of the vessel three or four years' salary for a most efficient one. This suggests the question whether there is not room for improvements in condensers? whether straight tubes therein are the most satisfactory, even though provision is made for the unavoidable expansion and contraction in the fastenings at the ends? Would the frailties of the condenser be permitted in a boiler? The Engineer-in-Chief, in his last report, says: "Fresh water for the boilers is almost as important as coal." This being so, it is most important especially for water-tube boilers (now a necessity) that the condensers should be perfect. Here I would like to emphasize also the importance not only of fresh water, but as far as possible of clean water, especially free

from acids and grease, both deleterious; the latter deposited on the interior surface of the boiler reduces its efficiency enormously. This suggests the question, Is the internal lubrication of engine cylinders a necessity? Oil is certainly a very serious nuisance when it reaches the condenser and the boiler. If "necessary," that lubricant least injurious should be used, and with it efficient means to prevent it reaching the condenser or boiler. For this an efficient filter may become also a "necessity." We are, however, at a loss to understand why engines of torpedo boats, which have the *highest piston speed, can be run without oil*, and other craft cannot!

Some two years ago, we were awarded the contract to re-tube the boilers of the torpedo-boat *Cushing*. The removed tubes were absolutely clean inside, although they had been in use some six years. Their condition was highly creditable to the engineer officer in charge, especially when we had just examined a yacht's boiler which had from $\frac{1}{8}$ to $\frac{3}{16}$ deposit of greasy matter on the inside.

I can hardly agree with Mr. Robison when he says, "no great efficiency in firing must be required to attain a good efficiency of the boiler." We think there are few places where efficiency pays better than in the fire room. We feel that this is so important that men should be trained in sufficient numbers to have at least one efficient fireman on each watch in each fire room, during activities like those during the late war, and that it should be his duty to initiate and superintend the green men during time of war, if trained men in sufficient numbers cannot be obtained.

Great trouble was experienced, Mr. Robison tells us, from inefficiency due to dirty fires and lack of opportunity to clean them. I would suggest the use of the highest grade coal. There are coals in this country unsurpassed in the world, and on shipboard none but the purest and best should be used. When coal room is so scarce, why take coal containing from 10 per cent. to 20 per cent. of foreign matter, when there are coals in abundance having not more than $2\frac{1}{4}$ per cent.?

During a test made by a board of naval engineers, of which Commodore Loring was president, a Ward boiler, having sixty-six

square feet of grate surface, burned fifty-five pounds of coal per square foot of grate for two continuous twelve-hour runs without cleaning fires; as much coal was burned during the last hours as through any of the preceding. At the close of the runs the remaining dry refuse was only 4.8 per cent., including what little coal had fallen through grates in spreading fires. The ashes were not burned as in some tests.

Touching the endurance and efficiency of water-tube boilers, Commodore Melville, in his report, cites the performance of the *Annapolis* and *Marietta*, both of which had been in service more than one year, and yet made excellent showing. I can add to this the performance of the Revenue Cutter *Hudson*, which distinguished herself by saving the disabled *Winslow* and her crew from the enemy's fire. The *Hudson* had been on "boarding duty" in New York harbor for five years, was ordered to the war, made the trip and distinguished herself, and returned to New York without any boiler repairs during six years of service. She certainly has an efficient engineer.

I cannot help regretting that I have not some data of the record of the *Monterey's* trip to Manila. It will be remembered that her boilers were built in 1890, now nine years ago; and she, a coast defense vessel, makes a 6,500 miles trip partly under her own steam.

John I. Thornycroft.—I have read Mr. Robison's paper with much interest, and agree with him in much that he has said, but *not* in the necessity for straight tubes. I think we must look to change in the condenser details to save our fresh water from having accidental additions of sea water.

In ships where the weight of machinery is not quite so important as in the destroyers, perhaps the construction of condenser proposed and used by Loftus Perkins, in which the condensing water was conveyed by one internal tube to near one closed end of the condensing tubes, which were only made fast in a tube plate at the other, would avoid the effects of expansion to cause leakage. Mr. Perkins said that his condensers were perfectly tight, but we are unable to secure this result by the

modern construction of condensers with straight tubes secured by glands at both ends. I think it is not possible to exactly determine where each part of the loss of fresh water takes place in a ship, but the safety valves are responsible for much, also the drainage of the many steam pipes, is imperfectly collected. The loss in the boilers should be very small, in externally-fired boilers with curved tubes of iron or steel, for in them the tube joints keep perfectly tight, and a considerable amount of sea water may be used without causing sufficient internal deposit to make it necessary to clean the inside of the tubes. Salt water, however, tends to cause corrosion of the generating tubes, and every effort should therefore be made to keep it out entirely, as corrosion is at present the greatest difficulty to be overcome with water-tube boilers.

The proposal made in his paper for short fires and very limited rate of combustion, must entail very much space devoted to the boilers. If this is at the expense of the room for the stokers, they will suffer the more from heat. At the same time the quality of coal available has much to do with the rate of combustion that can be maintained, and by the use of powerful fans the temperature of the stokeholds can be much reduced.

In order to save the crew from fatigue in a war ship, as far as possible, water-tube boilers are a necessity, I believe; but for this purpose they must be adapted to stand strong forced draft, so as to raise steam very quickly. Their weight, together with that of the coal they will burn in a certain time (depending on the proposed service), must be as small as possible, so as to give the best speed to the ship and reduce the work of the crew.

The necessity for internal cleaning of the generating tubes has not been proved for all kinds of water-tube boilers, I think; and as curved tubes afford means of withstanding rapid, irregular heating, and also allow a better separation of steam from the water in the boiler, I consider they are best for the purpose of steam supply in war vessels.

A. F. Yarrow.—The only reason why, I apprehend, curved tubes were and still are adopted by many makers of water-tube

boilers is that an engineer naturally and properly deems it necessary to make ample allowance for various rates of contraction and expansion in different parts of the same structure. Experience, however, indicates that in water-tube boilers having good circulation the elasticity of the tubes is sufficient to make the necessary allowance, and, as far as our experience goes, we have no reason whatever to regret having adopted straight tubes from the beginning.

I think Mr. Robison has done right in drawing attention to the necessity of greater uniformity of design in marine engine construction, and one cannot help remarking that in almost all the navies of the world one sees vessels of the same class and in large numbers with quite needless differences. I refer now more to torpedo boats, torpedo-boat destroyers, and such like, where, certainly, a great gain, in time of war, would be found if the spare parts suitable for one boat were available also for others.

I am quite aware that any one occupying a responsible government position cannot do what a private individual can, namely, give decided preferences freely to special firms and to special designs. I also am quite aware that it would be a very dangerous thing to tie the hands of contractors too closely by regulations which might affect efficiency of design, as this would, if carried too far, retard progress. Nevertheless, I do think a great deal might be done, certainly more than at present. For example, in vessels of the same class one meets with condensers two inches larger in diameter and four inches shorter in one vessel than in another, both of the same cooling surface. Surely there can be no charm or gain in any such differences, but if they were both alike, the same spare condenser tubes would come in. This is one of the many examples which can be quoted where a certain amount of uniformity might be adopted without possible objection and with undoubted gain; and in time of war it would certainly be a source of great convenience for the spare gear of one vessel to be adaptable to suit another vessel. I think, therefore, Mr. Robison has done a public good in drawing attention to what has hitherto been greatly disregarded.

Jules D'Allest.—Mr. Robison's article on the technical lessons to be drawn from the Spanish-American war, from the point of view of the marine engineers, is very interesting, and I do not doubt that his very judicious conclusions will be widely noted. It is with pleasure that I give my opinion on this work, as it expresses my ideas in all points as regards boilers.

The difficulty in obtaining trained firemen is encountered not only on men-of-war in time of war, but also even on merchant vessels in times of peace. Taking this into consideration, it is evident that when a large number of vessels are to be put into commission at one time, those that have the least complicated boilers will be able to make the longest cruise.

It is to be remarked that from the beginning of the war difficulty was experienced in obtaining fresh feed water for the boilers; that the tubes were rapidly fouled on both the water and the fire side; that the grates became dirty; that it was with difficulty that more than 25 pounds of coal were burned per square foot of grate surface per hour, and, finally, that it was of the greatest value to be able quickly to obtain steam.

It seems a logical conclusion from these conditions, that for military purposes water-tube boilers are the best, provided, of course, that they must be easily worked and easily cleaned. The working will be easy if the boiler contains sufficient water to render the maintenance of a proper water level no more complicated than with ordinary boilers. The easy working will be equally aided if complete combustion can be secured even with bad firing. Mr. Robison is right when he says that this is a difficult requirement to satisfy; but while not wishing to unduly praise our own boilers, I must state that this is the end which we have always sought, and which we have attained. For this purpose we have coupled our boilers in pairs, as is well known, with a common combustion chamber, and we have forced the firemen on our ships to fire alternately these two boilers, and never to fire them together. In this way, if one of the fires is too heavy, the other is, on the contrary, at the same moment, not heavy enough. The gases from the heavy fire are burned *in the common combustion chamber* by the air arriving in excess by way of the light fire.

We have also succeeded in obtaining in practice and over very long distances a high rate of combustion that was very economical by using what is called methodical firing, something that has been well-known but very seldom used except on trials. Thus, if, say, 20 pounds of coal are to be burned per square foot of grate surface per hour, the total weight for a furnace for a given time is divided into several small charges of say 50 pounds each, which are used at regular intervals varying from five to ten minutes. If briquettes are used the number of briquettes to be used is known in advance. Every five minutes an electric bell sounds automatically in the fire rooms. At this signal, for example, the even-numbered furnaces are fired, while at the following signal the odd-numbered furnaces are fired. By this simple means it is readily seen that we burn under the most excellent economical conditions much more coal per square foot of grate surface per hour than could be done by leaving the firemen free to fire the boilers in their own way.

It seems to me correct that straight tubes, with the interior accessible from each end, are the best. They can be readily cleaned, and a clean boiler produces steam freely and is less liable to accident. It seems also correct that these tubes should not be too small. In that case cleaning would be impossible, and they would be quickly choked by scale. It is evident now that on cruising men-of-war sufficient fresh water can be obtained only with great difficulty, and from this point of view boilers capable of using, if not pure sea water for feed water, at least salty water, must be very highly desirable.

Mr. Robison is quite correct in what he has said concerning the maximum allowable rate of combustion. A war vessel should have sufficiently powerful boilers to obtain the extreme trial speed without burning over about 25 pounds of coal per square foot of grate per hour; this because during any prolonged period at sea the forced-draft system may get out of order, and because it may be necessary to use coal of such a quality as will render impossible a high rate of combustion without rapidly destroying the grates.

John Platt.—The importance of the matter of *uniformity* in the spare parts and stores for different ships cannot be overestimated. But there are other things which make absolute uniformity, even in such desirable things as grate bars and boiler tubes, an uneconomical desirability. In speaking of boiler economy, later on, this subject will again be referred to.

The great increase in the materiel of the navy in time of war, and the fact that inexperienced men have to be employed in the working of the boilers, has an important bearing on the type of water-tube boiler to be employed. The boiler must not be of such a design and construction that a small departure from the proper method of working will affect it to such an extent that a great reduction in economy, and perhaps disaster, will be the result. That certain boilers are open to this objection has been shown by the working of the water-tube boilers on some of the biggest ships in the British Navy, even with the regular service engineers and firemen, the greatest care and the assistance of the boiler people themselves, low economy and trouble have existed. It has been pointed out that the fire room is perhaps more seriously affected by war conditions than any other part of the ship; hence more serious trouble may be looked for when the service-trained men are not attainable.

The small tube water-tube boiler, from its construction, is of necessity the one which will best serve the requirements set forth that it must be possible to obtain full boiler power on short notice.

Great stress was laid by Mr. Robison on the coal question, and of the necessity of economizing the same. To get full power with the cylindrical boiler at short notice it was necessary to have all fires in proper condition and to be constantly using coal. With the boiler with small curved tubes—even if the boilers were cold—with fires laid, full steam pressure would be obtained in from fifteen to twenty minutes.

In installing water-tube boilers in big ships provision will be made for the ready cleaning of the outside of the tubes. This can best be done by having compressed-air pipes run along the fire rooms, so that a hose can be coupled and all soot and dirt

blown out. This is a marked improvement over the steam jets usually employed, and was suggested to the writer by Chief Engineer Freeman, who used it on the *Nashville* with great success.

Scale on the inside of the tubes has been urged against the use of the boilers with small bent tubes. The best thing to do is to refer to past experience to show that in such a boiler, properly designed, where the tubes discharge into the upper drum above the water level, the circulation is so rapid that all deposit is carried through the small tubes and eventually settles in the lower drum, from which it is readily blown off.

We can refer to the boilers of the U. S. torpedo boat *Ericsson* as an excellent example. These boilers were in use between four and five years, they never received any special care, and whilst in use before Santiago were repeatedly salted, from conditions over which the officers in charge had no control. Notwithstanding all this, it was found on taking some tubes from the boiler and cutting them up that they were in thoroughly good condition and free from dirt and scale.

The action of dirt in the water when used in "light tubulous boilers" in torpedo boats is spoken of as having caused severe priming at high speeds. This class of priming is not caused in the case of the small-tube boilers where the tubes are above the water level in the top drums. The tubes being designed to carry over steam and water, the water being carried down to natural water level by the separator, and the steam escaping to the steam space, renders this boiler free from the very serious defect of carrying over water with the steam which is delivered into the main steam pipe, even under the most unfavorable conditions.

Stress is laid upon the fact that under conditions of war, through dirty fires, etc., the combustion of coal per square foot of grate was abnormally low. This being the case, it is advisable to have a boiler of such a design that a comparatively high degree of forcing can be resorted to, so that even with the fires in bad condition, as large an amount of coal as possible can be burned. As the burning of only twenty-five pounds of coal per square foot of grate leads to the use of a larger boiler than necessary for naval

work, means should undoubtedly be taken to make it possible to obtain better results. It is possible to design a boiler that is highly economical (for big ship conditions) under a high degree of forcing. A high air pressure can be procured, and with this the greater part of the dirt is blown into the stack and the fires kept in a much better state. In English destroyer practice they run the three-hours' trials, burning between sixty and seventy pounds of coal per square foot of grate, without cleaning fires, and at the end of the trial the fires are in good condition, and there is but little refuse in the ash pans.

In considering what is required to properly meet war conditions, stress is laid upon uniformity of design. This is undoubtedly, as before mentioned, a very important factor, but in the main steam plant it must not be allowed to unduly influence economical working conditions. The main reason why the length of the grate cannot always be the same, is the fact that sometimes from the nature of the general design of the vessel the boiler space available is such that to get in the largest possible amount of grate area a difference in length is necessary. The grate should be as short as possible, and should, under no circumstances, be over seven feet in length; it is only the great height of the fire box in certain water-tube boilers which makes it possible to properly fire this length.

Exception must be taken to the possibility of obtaining a constant length of boiler tubes. It is not possible to build an *economical* boiler for ships of different types, to meet the very different service conditions demanded, and at the same time to keep a fixed length of tube. A large grate area is desirable, but for a given power too large an one is not to be recommended. A small fire, properly worked, can be made to give better results than a large one. Because a very large grate area is necessary in some types of boiler on account of the boiler being in itself uneconomical, the same large area should not be demanded in a more economical type in which the coal can be burned to better advantage. The burning of only 25 pounds of coal per square foot of grate, on contract trials, which are made under most favorable conditions, is open to objections, and can be made

to work against the best interest of the boiler plant. If very valuable room in the ship is taken to put in a larger boiler plant than is necessary for a given power, and the power obtained on the trial with this low rate of combustion, it is quite possible under such conditions to use a type of boiler that under adverse war conditions will not develop the required amount of power. As a boiler of high efficiency at high rates of steaming can be obtained, the economical burning of a much larger amount of coal per square foot of grate should be insisted upon at the start.

If the above conditions are fulfilled, it will also follow that the boiler will be capable of raising steam from cold water in the shortest possible space of time.

There need be no fear that a battery of water-tube boilers will not be divided into small enough units. The fear is that the units will be too small. The disadvantage of two small units is that this means a large number of extra fittings valves, and connections to the main steam pipe. But a more serious objection still is the increased number of water levels that have to be taken care of. The smallest number of water levels possible, considerate with the economical overhauling of the boilers, should be insisted upon. For a battery of 18,000 horse power for naval service the writer would suggest twelve units; each unit having one main steam drum and two entirely separate fire-grate chambers, the grates being about 6 feet 9 inches long.

Boilers should undoubtedly be accessible to repairs and cleaning, but it is even more desirable to have a design in which repairs are reduced to a minimum. Most of the repairs are rendered necessary by unequal expansion and contraction in the boiler, due to the sudden raising of steam and rapid temperature changes. Under the circumstances repairs will be the least where this expansion is taken care of, as it so successfully is in the class of boilers with small curved tubes, the tubes entering the top drum above the water level.

The ideal boiler sought after will, we think, have to be capable of sustaining a high forced draft economically. First, so that as large an amount of coal as possible per square foot of grate

can be properly burned, not that under trial conditions a larger amount than 25 pounds per square foot is necessarily desirable. Secondly, from constructive reasons the boiler that will meet these forced conditions will be the most economical possible under ordinary rates of steaming.

It is the fact that the "comparatively direct and unobstructed course of the gases of combustion renders them uneconomical with high forced draft," which has made possible the many serious objections raised against water-tube boilers on account of lack of economy.

Boiler-room space can only be brought down to that taken up by the old type of boiler by the use of a boiler that is capable of economical forcing. It will be noted that in all cases the writer couples economy with the forcing.

The number of attachments can best be kept small, and the boiler room work rendered reasonably easy by the use of a boiler which does not from structural reasons render a very large number of units a necessity.

The complete combustion of the fuel can be obtained where too great a width and length of grate is not in question, provided the combustion chamber is very large, and the passage of the gases properly guided by walls of tubes through a large space into which they can expand before reaching the uptake. A high combustion chamber renders the use of an observation window possible, and with this it is very easy to prevent holes in the fire.

The water levels can be kept steady by the use of feed-water regulators, but, as before stated, the fewer the number of levels to be looked after the better. In big ship boilers there is no difficulty in making the top drum large, and thus provide a large area of cross section at the water level.

The plugging of small tubes is such an expeditious and easy matter, and with a good design of curved-tube boiler the repairs to the tubes so small, that the writer can not at all agree with the view that the straight-tube boilers can be more readily repaired. The cases of the *Cushing* and *Ericsson* can be cited. After four and five years' service it was found that only seven

or eight tubes had been plugged, none at all having been replaced.

The paper by Mr. W. R. Cummins in the November JOURNAL on "High Pressure at Sea" gives a good idea of the different types of water-tube boilers, and the writer generally agrees with his deductions. In writing of the Thornycroft boiler he is unfortunately guided entirely by the design of those used in torpedo-boat practice; for the big ship service important improvements are possible. On page 1079 he states that "the passage traveled by the gases before they reach the uptake is only a little over five feet." This leads him, in his deductions on page 1082, to state that the boiler, although it burns the fuel better, it does not utilize the heat as well as those of the large straight-tube type. In the new design the gases have to travel from ten to twelve feet, a great enough distance to make them utilize the heat as well as any of the boilers he names. The design also allows for a much larger amount of water, and hence the difficulties owing to irregularities of feed are done away with. This new and improved design, therefore, does away with the only two objections he was able to raise to the class to which it belongs. There is a further advantage, which was not touched upon, and that is the great reduction in weight made possible by their use. Here the reduction is enough to make it of real moment. In the case of some of the boilers of the straight, large-tube variety the reduction in weight is so slight that the same advantage does not exist.

The successful installation and operation of over 600,000 horse power of water-tube boilers for marine service by one firm can surely class this as more than an experiment, particularly as very many of them are used under the most trying conditions of boiler service, with the extremest possible driving, and with high economy. Surely if this has been the case, under the easier and more satisfactory conditions of big-ship service they will continue to be as successful as in the past. This success has also been attained without the aid of either the "feed heaters, air heaters, and all sorts of economizers" referred to by Mr. Robison.

Change in conditions has made improvements in detail and even in general design possible, and further experience will always, as in the past, make it possible to still further work up towards the high ideal sought after by Mr. Robison in his very able treatise on the subject.

W. D. Hoxie.—Mr. Robison does not refer to the use of water-tube boilers in the merchant marine, but all that he says regarding their advantages for ships of war holds good for ships of the carrying trade.

It was a stubborn fight the early builders of stationary water-tube boilers had, when it was thought by most purchasers that the only boilers that could be depended upon to make steam continuously were the cylinder, two-flue or the return-tubular type. It is a little remarkable that the industry in which water-tube boilers were most extensively used was the manufacture of sugar, for, of all stationary power plants, the sugar house comes nearest to a transatlantic liner. A sugar refinery runs night and day, the demands on the boilers are continuous and severe, and during the period of boiling sugar in vacuum pans the boilers are operated under a strong forced draft. Since the early seventies this type of boiler has been used for nearly all kinds of manufacturing, and in later years has played a most important part in the generation of electricity. To-day there is hardly a large electric-light or power plant constructed but water-tube boilers are installed. At the last electrical exhibition held in New York City, it was shown by one concern building water-tube boilers that they had in successful operation enough boilers in use in the generation of electricity to supply a chain of 16-c.p. incandescent lamps, twelve feet apart, that would reach around the world.

Every year adds many converts to the already long list of ship owners using water-tube boilers, and there is no better proof of their entire satisfaction than is evidenced by the increasing number of new vessels having them installed and the frequent replacement of cylindrical boilers with those of the water-tube type. Especially is this true on the Great Lakes of North

America, where competition is exceedingly active, and where a ton of freight is carried cheaper than on any other body of water in the world. Space and weight are saved for the same horse power developed, a higher steam pressure is carried with safety, the steam consumption of the engine is thereby materially reduced and greater economy obtained.

If properly constructed, of *straight* tubes that can be purchased in the market, with tube ends that are accessible, the cleaning of the boilers, both inside and out, may be thoroughly and quickly performed. Generally, such a boiler can be repaired by the ship's staff without calling for the assistance of boiler makers and the use of shop tools. A few new tubes and the water-tube boiler is as good as new; there are no furnaces, crown sheets or combustion-chamber plates to drop and bulge, from whatever cause.

After the recent war with Spain, it was found necessary to renew the furnaces of the battle ship *Indiana*, requiring the services of not only the New York yard, with its gang of boiler makers, but the furnaces had to be corrugated in a particular shop; all this detained the ship at the yard for four months. Had the *Indiana* been equipped with say ten water-tube boilers of the straight-tube type, the tubes being expanded into place with ends accessible, the first three rows over the fire might have been removed and replaced, whether blistered, burned or bent from salt and oil in the feed or from any other cause, and repairs made entirely by the ship's talent in not more than three weeks' time.

One of the largest firms shipping ore from Lake Superior equipped a year ago a new 6,000-ton freighter, with water-tube boilers, and when asked what they considered one of the greatest advantages attained by the use of these boilers, replied: "We can load our vessels at the rate of a thousand tons an hour and unload them almost as quickly. This means that our stay in port is only a little over six hours. In that time we can blow a boiler down, make a joint on boiler, steam piping, grind in a leaky safety valve or renew a tube, can refill and have full steam and be ready to sail for destination as soon as the ship is loaded,

and yet have no fear of straining the boilers from unequal expansion in getting steam quickly. With our old cylindrical boilers we would just about have them cooled off ready to work upon by the time the ship was loaded and the rest of the time placed upon the repairs, refilling, and slowly raising steam, means detention of the ship and loss to us."

Mr. Robison makes a statement as to the design of a water-tube boiler, but does not refer to materials of construction. There should be no more cast iron, malleable cast iron, or cast steel used in the pressure parts of a water-tube boiler than is now allowed in the construction of a cylindrical boiler, which is *nil.* This is especially important where high-pressure steam is carried. Any of the cast metals placed under pressure are unreliable, even those that are so called annealed, which process of annealing means the burning out of the carbon in the casting, leaving small holes which render the casting porous. The difficulty in obtaining sound steel castings is so well known that their use for pressure parts of boilers is exceedingly unwise, if not positively dangerous.

The water-tube boiler that is to stay in service should therefore be constructed of open-hearth forged steel and drawn tubes, with only cast metal in use for grate bars. The most serious repairs would then consist of a new set of tubes, for tube-end connections made of forged steel cannot crack, even if the boiler were neglected and badly burned.

There is a prevailing opinion among some designers that all water-tube boilers must be constructed of material representing a minimum of weight for a maximum of heating surface. Such boilers have a service to perform, and a good one, namely, in the torpedo boat or destroyer, where the weight of boiler with water per square foot of heating surface should not exceed twelve or thirteen pounds; but no water-tube boilers built on these lines has ever been used in the merchant marine, and it is very doubtful if they will meet with lasting favor in the larger vessels of the navies, as their tubes and casings are so very light that they suffer greatly from interior and exterior corrosion, which soon renders their sea service questionable.

The pendulum of opinion as to weights is swinging to its limit. It must return, and when it does, will finally come to rest at the water-tube boiler, whose weight is about midway between the heavy cylindrical boiler and those of the express type. Such a boiler can go to sea without fear of breakdowns, and when called upon to steam continuously on long voyages, will be found to contain sufficient metal to perform all the duties now required of the cylindrical boiler, and possess advantages already enumerated, that will cause it to outstrip its old rival in the race for supremacy.

George W. Melville, Engineer-in-Chief, U. S. Navy.—While appreciating the many good points in Mr. Robison's article, I am sorry to say that my first impression on reading it was a disappointment. I have learned to appreciate Mr. Robison's ability very highly, and the array of facts which he presents is disappointing simply because, it seems to me, he has not made the most of his case. I know exactly why this is so, and am glad of the opportunity to state, for the benefit of those who may not understand the reason, that Mr. Robison's duties as one of my assistants for some months past, have kept him so very busy that it was simply out of the question for him to give the time and attention necessary to present his paper in the finished form in which it would undoubtedly have appeared had the circumstances been different.

With regard to the matter of an ample supply of fresh water for the boilers, I think it is pretty well understood, by those familiar with the service, why it was that the trouble arose. We had not had the opportunity before the war broke out to prepare the distilling ships, which we began as soon as funds were available. The *Iris* was finished in time to go to Montauk Point to supply pure drinking water to the army, and it may not be amiss for me to call attention to the fact that on test her capacity of drinking water which would stand the nitrate of silver test, was found to be 75,000 gallons per diem, while of water fit for boiler feed she made over 100,000 gallons per diem.

The advantages of a distilling ship, rather than a tank steamer,

for supplying water to a fleet, are very obvious. The distilling ship has a very economical triple-effect evaporating apparatus capable of supplying over twenty tons of water for each ton of coal burned in the boilers. As a consequence, if the bunker capacity is 3,000 tons, it gives us a potential water supply of 60,000 tons, while even a large tank steamer would not have a capacity of more than 5,000 or 6,000 tons. In addition, with a distilling ship, we can supply absolutely pure drinking water for large bodies of men, while the "tanker" must take the water at the nearest source of supply and trust to luck for its being fit for drinking purposes, if that should be desirable.

I may say in connection with this matter of water supply, that we are increasing the evaporating plant of all our ships where there is sufficient room, by installing additional evaporators, so that even without the distilling vessels, there will be less trouble in the future.

I think Mr. Robison's dictum, under No. 6, on page 1003, that "not more than about twenty-five pounds of coal per square foot of grate can be burned for any length of time," is too dogmatic an assertion, and hardly consistent with facts. The rate of combustion in the transatlantic liners, nearly all of which now use forced draft, is considerably higher than this. The amount that can be burned does depend, in the last analysis, on the skill of the firemen and their ability to keep the fires properly cleaned. Mr. Robison's point is made, of course, with the idea of providing such an ample grate surface that inexperienced firemen will still be able to get adequate power from the machinery.

I cordially indorse his remarks on the subject of uniformity in designs, for it is what I have been urging in my annual reports for some years past. The advantages of uniformity appeal to every one connected with the Navy, as shown by the remarks of Captain Mahan in McClure's Magazine for January, where he commented on the great advantages of having all the units in a fleet absolutely alike. This holds just as much with regard to the machinery as to the hulls or the guns.

Mr. Robison makes a good point with regard to the desirability of having the boiler power in small units, as enabling them

to be laid off one at a time for cleaning or repair without materially reducing the aggregate boiler power; but obviously there is a good deal to be said on the other side, both with regard to the first cost of the increased number of fittings, the increased weight and the difficulty of maintenance where there are so many small units. I am certainly not prepared to indorse his statement in the form he has put it. I should rather have been inclined to state the proposition as recommending the desirability of increasing the number of units as far as practicable without sacrificing other considerations, in order to provide for cleaning and repair.

The conclusion which Mr. Robison reaches finally, that water-tube boilers are tactical necessities, of course has my hearty indorsement. If the battle of Santiago taught nothing else, it certainly made very clear the absolute necessity of water-tube boilers for our modern war vessels.

With regard to the type of water-tube boiler, so much has been said that it hardly seems worth while to discuss the matter again. My own personal preference is for boilers with straight tubes, yet at the same time, it cannot be questioned that the small-tube boilers also have many good points and have some advantages over the boilers with straight tubes. I have no doubt that as time passes and the different varieties of water-tube boilers are thoroughly tested in every-day service, we shall finally discover one or more forms of water-tube boiler which are on the whole most satisfactory, and then they will become the standards. Mr. Robison has made the subject of water-tube boilers a very careful study, and anything he says on the subject is sure to merit careful attention.

J. K. Robison.—I heartily thank the gentlemen who have so kindly dealt with my remarks and who have added so greatly to the value of the paper by their discussion of it. Our Engineer-in-Chief says: "If the battle of Santiago taught nothing else, it certainly made very clear the absolute necessity of water-tube boilers for our modern war vessels." Here is settled the great question of water-tube boilers, at least as far as our Navy

is concerned. The details are less important and will soon work themselves out satisfactorily.

In regard to the maximum rate of consumption allowable on war vessels on the trials, I must say that I consider "thirty to thirty-five pounds" per square foot of grate surface per hour none too low. It is to be noted that in this war we had the best coal in any market, and that we had quite as good firemen as we are likely ever to obtain during a war, yet we seldom, if ever, after having been under way for any considerable length of time, were able to burn over thirty pounds of coal per square foot of grate.

On one occasion, at least, this is the best that could be done with four inches of air pressure in the fire room, and this on a ship—the *Oregon*—that burned somewhat more than this figure on the trials with an average of but one inch air pressure. It seems to me that to adopt this dogma would be simply to carry into effect the knowledge derived from our war experience, and that it would simply extend to all war ships the rule we have had for many years, limiting the forced draft on our battle ships. I think there are few Atlantic liners that burn regularly over thirty-five pounds per square foot of grate surface per hour, and it is to be remembered that on these ships forced draft conditions are the normal ones.

In regard to the matter of spare boiler and condenser tubes, it may be worth while to say that we carry the longest tubes of each diameter as a stock of spares. In an emergency it has often been found best to waste a few inches from the end of the tubes and thus secure a tube fitted to a short boiler or condenser.

I feel bound to state that while I am sure that a boiler that will perfectly meet naval demands and conditions must have straight tubes, it is not by any means clear to me that among present designs the straight-tube boilers are the best for all purposes. Freedom of expansion and the quick raising of steam are necessary as well as accessibility for cleaning. There are patent advantages and disadvantages for each type. This subject has been very thoroughly discussed already.

The desire not to be wearying must be my excuse for not having done more than indicate lines of reasoning that I am sure all engineers follow.

THE PRODUCTION OF METALLIC TUBES BY EXTRUSION.

[Reprinted from "Engineering."]

At the spring meeting of the Iron and Steel Institute in 1896, a paper was read by Mr. Perry F. Nursey describing the process of, and the machinery for, manufacturing metallic bars of any section by extrusion at high temperatures. This system is the invention of Mr. Alexander Dick, and by it all kinds of metallic sections are produced, from a simple round wire to complex designs with re-entering angles, which it would be impossible to roll, by forcing metal, heated to plasticity, through a die under hydraulic pressure. These sections are all solid, but since the reading of that paper, which was published by us at the time, Mr. Dick has made the important discovery that copper and its alloys in a heated and plastic condition can be separated, and, provided no air has access to it to oxidize the fresh surfaces, they will reunite by simple pressure. A true weld is thus formed which it has been found impossible to rupture. Upon this discovery Mr. Dick has founded and perfected a system of producing metallic tubes of any section by the same process, and their manufacture is now being carried on concurrently with that of the solid sections. Of course we do not overlook the fact that the principle of extrusion has been applied in the production of leaden pipes and leaden rod for the manufacture of projectiles for small arms. But, in those cases, the lead is pressed at a comparatively low temperature, whilst in the present instance the metal has to be operated upon at a very high temperature, namely, that of plasticity, or about 1000 degrees Fahrenheit.

The process of manufacture is carried on by means of a press. The machine is 16 feet in length, 6 feet wide, and 5 feet high over all. It consists mainly of the compressing cylinder or container,

and the hydraulic ram. The heated metal is placed in the cylinder, at one end of which is the die, and upon pressure being applied at the opposite end the plastic metal is forced through the die issuing therefrom as rods, or as tubes, of the required section and of a length governed by the quantity of metal placed in the container. This container has not only to withstand the high temperature of the metal, but it has also, whilst under the influence of that temperature, to meet the severe strain brought upon the interior by the resistance of the metal to the pressure of the hydraulic ram in forcing it out through the contracted area of the die. The construction of the container was, therefore, an anxious matter, and the designing of it gave some trouble, but at length all difficulties were overcome and every working requirement amply met. The container, which is 2 feet long and 2 feet in diameter externally, has an inner liner of cast steel. The internal diameter of the liner varies in different containers from 5 inches to 8 inches, according as to whether it is wanted for pressing a small or a large charge, the container being changed as required. The liner is enclosed within a series of cylinders of ordinary mild steel spaced about $\frac{3}{4}$ inch apart, the annular spaces being filled in with a non-conducting material composed of crushed granite mixed with a small proportion of borax. The container is mounted on trunnions and fitted with worm gearing for bringing it to a vertical position for being charged with metal and restoring it to the horizontal for the operation of pressing.

The die plates are made of tungsten steel, and they are formed with either one or several openings, each opening being, in the case of rods and bars, of the section required to be given to the article produced. In the case of tubes there is a mandrel in the center of the opening in the die plate. This form of die is shown in Figs. 2 and 3, Fig. 2 being a vertical section and Fig. 3 a plan view at the back of the die, or that portion which presents itself to the incoming metal in the operation of pressing. Upon the plastic metal meeting the sharp edges of the ribs or wings of the die, the stream becomes divided, and is conducted in several streams to the mandrel, around which the incoming metal is pressed. Here the divided streams of metal are re-united as a

tube, and become firmly welded together, so that it is impossible to discover the points of junction in the finished tube. This re-union is dependent upon the exclusion of the air, which would otherwise cause oxidation of the surfaces of the metal, and prevent them uniting. A singular verification of this is shown by the fact that for a few inches at the front end of every tube the metal is never united, as will be seen from Fig. 1. It might be thought that this was due to the cooling action of the die on the metal. This, however, is not the case, inasmuch as at the commencement of every run the die is heated to a cherry red, the initial severance being solely due to the presence of air in the die, and the subsequent re-union of the metal, to its absence.

The die-plate is mounted in a holder, in which it is easily fixed, or from which it is readily removed, as different sections are required to be pressed. As it is necessary to heat the die and its holder previously to each pressing operation, as already mentioned, the die is fitted into a shouldered recess in the holder, which is coned to seat into a hollow metal block. This block is firmly held in position during the operation of pressing by a pair of gripping jaws actuated by hydraulic power. The die holder and the gripping jaws are carried in a strong crosshead. The metal is forced out of the container and through the die by an hydraulic ram 20 inches in diameter, and working under a pressure of two tons per square inch. The ram has a prolongation or extension of reduced diameter, which forms the plunger of the container, entering it at the opposite end to that at which the die is situated. A different plunger is used with each container, the diameter varying to suit the internal diameter of the container. On starting to work each day the container is first heated up by gas with a Bunsen burner, which quickly brings the liner to the temperature necessary to prevent the first charge of metal receiving a chill. The container does not require reheating, as the liner remains red hot after each run.

Such in general is the arrangement of this ingenious system of tube production. Its operation may be best described from our own observation during a recent visit to the Delta Metal Works, Pomeroy street, New Cross, London. The machine was

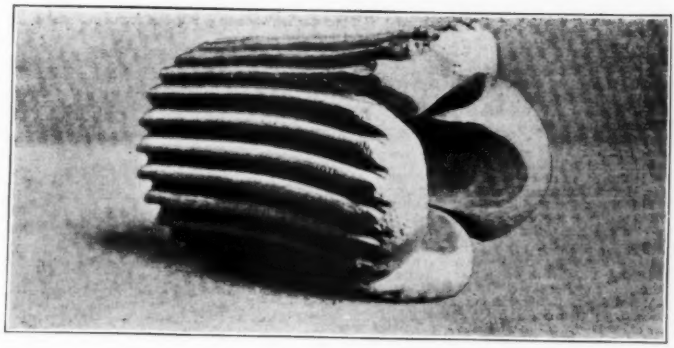


FIG. 1.

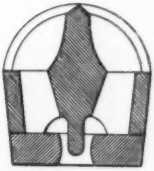


FIG. 2.

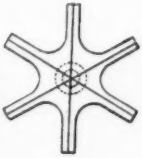


FIG. 3.

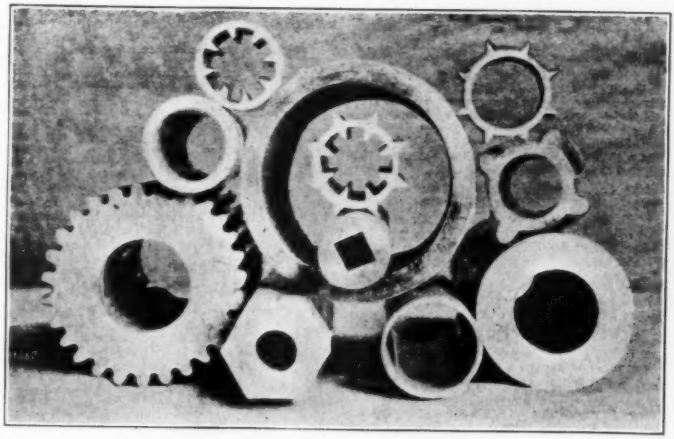


FIG. 4.

running on tubes of 2½ inches and ¾ inch in diameter respectively. In the case of the smaller tubes, four were produced at each pressing, whilst in the case of the larger tubes only one was produced at each run. A charge having just been put through, the opening at the front end of the container—that next the die—was closed by a removable plate or stopper, and the container was up-ended in a vertical position with the closed end at the bottom. A billet of delta metal weighing about 1½ cwt. and heated to plasticity was then placed in the container. The diameter of the plunger, and that of a loose block which is placed between it and the charge, being less than the diameter of the steel liner, the plastic material when under pressure would be forced backwards between the block and the liner were it not restrained. In order to prevent this back flow taking place, a dished steel check disc which is less plastic and more rigid than the heated metal at the working temperature, is first placed on top of the charge, and when the pressure is brought on the disc is expanded and completely fills the bore of the liner, thus effectually preventing the back flow of the metal.

The loose steel block just referred to was then placed upon the check disc, and having been previously heated, it prevents the cold end of the plunger chilling the charge of metal. The plunger being of smaller diameter than the liner, there is no fear of the latter becoming chilled by the former. To preclude all chance of such an occurrence, however, the back of the loose block is recessed and receives a corresponding projection on the front end of the plunger, which is thus maintained in a central position and is prevented from coming into contact with the liner. The block having been inserted, the container was brought into a horizontal position, the front stop plate removed, and the container run up to the die block which, with the die, had been previously heated. The hydraulic pumps were then started, and in four minutes the charge was expelled and had become connected into lengths of tubes of the diameters stated. The gripping jaws were then released and the ram continued its forward travel, pushing out the remainder of the metal or stump, together with the die and its holder as well as the check disc and the loose block,

leaving the container perfectly clear for the next charge. The tubes were then cut off from the stump or fag end of the charge; the die and holder replaced by others; the stopper of the container fixed in place, and the container up-ended for another charge, a similar cycle of operations to those just described being then carried out.

We thus have an ingenious application of the principle of extrusion to an important industrial purpose. That the system possesses great possibilities is evident from the variety of tube sections that are produced by it in delta metal—which itself embodies several important physical characteristics. The wide range of tube sections produced will be seen on reference to Fig. 4, which illustration is prepared from a photograph of some of the sections ordinarily being made. The process, moreover, improves the quality of the metal owing to the great pressure put upon it, in the same way that Whitworth steel is improved by compression. Some tests made at Woolwich Arsenal with delta metal bars produced by extrusion, show a tensile strength of 48 tons per square inch, with 32.5 per cent. elongation in 2 inches, against 38 tons per square inch tensile strength and 20 per cent. elongation of rolled bars of the same metal. Compared with ordinary yellow metal the increase in tensile strength is 24 per cent., with a proportionate increase in elongation. In some tests made in France with rolled yellow metal bars, the tensile strength was 50.5 kilogrammes per square millimeter, with 18 per cent. elongation in 10 centimeters; whilst extruded bars of the same metal gave 54.6 kilogrammes per square millimeter, with 25 per cent. elongation in 10 centimeters. Rolled delta metal bars gave 73.3 kilogrammes per square millimeter, with 28.8 per cent. elongation in the same length; whilst extruded bars of that metal gave 76.6 kilogrammes per square millimeter (48.6 tons per square inch), with 29.8 per cent. elongation.

That the extrusion process considerably increases the strength of tubes is shown by some tests, in which the mean bursting pressure of three samples of extruded brass tubes 1.236 inches in diameter by 0.073 inch thick, was 6,570 pounds per square inch, which, by the well known formula

$$p = \frac{D^2 - d^2}{D^2 + d^2} f,$$

in which

p = bursting pressure in pounds per square inch,
D = outside diameter in inches,
d = inside diameter in inches,

gives a value of 54,000 to f for extruded brass tubes, whereas in ordinary solid-drawn brass tubes the value of the constant f is only 30,000, and even for manganese-bronze tubes only reaches 44,500. With regard to tensile strength, pieces of extruded brass tubes were tested longitudinally and transversely, the mean of six tests of the former giving an ultimate strength of 31.5 tons per square inch and 29.3 per cent. elongation, the six transverse specimens giving a mean of 28.8 tons per square inch with 9.8 per cent. elongation.

The development of the extrusion system of manufacturing metallic bars and tubes is shown by the circumstance that there are no fewer than nineteen presses on Mr. Dick's principle in operation in this country and on the Continent, whilst plant for three more is being laid down. The presses already in operation are at present turning out solid sections only, but they are all being fitted with the necessary appliances for the production of tubes by extrusion.

INDICATOR DIAGRAMS OF MULTIPLE-EXPANSION ENGINES.

By B. C. Ball, Member.

A few years ago the writer worked up a system for drawing indicator diagrams for multiple-expansion engines which he believes to be original in some respects, and which has some points of advantage over any other system with which he is familiar. Mention was made of it in a paper presented by the writer's father, Mr. F. H. Ball, to the American Society Mechanical Engineers, vol. xv., page 771.

Almost all the methods in general use for constructing theoretic indicator diagrams disregard the fact that the amount of compression of steam into the clearance spaces has an important effect upon the relation between the diagrams from the different cylinders, as well as upon the economy of the engine. It is generally assumed that the compression will fill the clearance spaces, and no further attention is given to that part of the diagram. In actual practice this is very seldom the case, and tests have been made which show that, for the sake of economy, compression should not fill the clearance space. Prof. D. S. Jacobus conducted one such test, and reported the results to the American Society Mechanical Engineers in a paper, vol. xv, page 915. But the object of this paper is not to discuss the question of what the compression should be, and this was only referred to, to show that it is not due to a faulty engine that the compression does not fill the clearance spaces.

The effect of varying compression in engines having moderately large clearance becomes very important if we want to know accurately what results can be obtained under certain conditions. For instance, it is possible to increase, to a considerable extent, the I.H.P. of a compound engine by simply making

the high-pressure valve close later for compression, without changing any other condition. So to get accurate results we must take the compression into account; and this is true, not only in drawing diagrams, but in combining them also.

In constructing the following diagrams no allowance will be made for the many deviations from a perfect diagram, such as wire-drawing of steam through ports, &c., for such deviations are very different in different styles of engines; and as these diagrams will be used to illustrate two different methods of combining diagrams, they will show more clearly the points to which I desire to call attention, if there are no losses except those due to free expansion into the clearance spaces at admission and into the receiver at release. The losses due to wire-drawing, rounding of corners, &c., must be determined for each particular case, when the peculiarities of the engine under consideration are known.

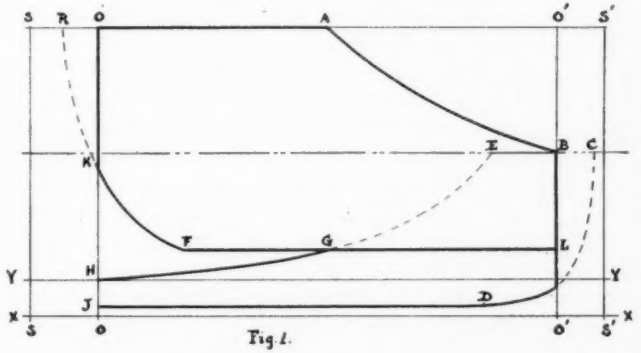


Fig. 1.

Fig. 1 shows the construction of diagrams for a compound engine, the following data being assumed: initial pressure, 120 pounds, absolute; vacuum, 11 pounds per square inch in the cylinder; ratio of expansion, 8; clearance in cylinders, 15 per cent. in the high pressure, and 10 per cent. in the low pressure; cut-off 0.5 in both cylinders; valve diagrams known. The expansion and compression curves will be assumed to follow Marriott's law.

Draw the limiting lines of the cards, $O\,O'$, the clearance lines $S\,S$ and $S'S'$, the vacuum line $X\,X$, the back pressure line of low-pressure card $J\,D$, atmospheric line $Y\,Y$, and line of initial pressure $O\,A$. Then $\frac{120}{8} = 15$, locates H; and, A and D being given, draw expansion curves $A\,B$ and $H\,E$, and compression curve $D\,C$, carrying each of the latter up to the horizontal line through B. Then, knowing the cut-off in the low pressure cylinder, G is determined and $G\,L$ drawn. If, instead of the cut-off in the low-pressure cylinder being given, the receiver pressure, or more correctly, the initial pressure in the low-pressure cylinder, is given, G will still be determined by the intersection of this line with the expansion curve.

The line $G\,L$ depends upon three conditions, viz: the relative position of the cranks, the volume of the receiver, and the ratio of the cylinders. With receivers such as are ordinarily used, which consist of steam chests and connecting pipes between them, the back-pressure line of the high-pressure card will be practically horizontal, regardless of the position of the cranks. But with engines which have very small receiver volumes, this line, $G\,L$, must be located carefully, and as engines of this class almost always have their cranks at 180 degrees from each other, this line can easily be drawn as an expansion curve, using for the clearance volume the combined volumes of clearances of both cylinders; the total receiver volume, including all steam chests subject to receiver steam, and a volume $\frac{V}{R-1}$, when $V =$ volume of low-pressure cylinder, and $R =$ ratio of the cylinders.

Constructing a compression curve from F, finishes the diagrams, and the cylinder ratio is determined accurately by finding the ratio between the two lines $B\,K$ and $C\,E$, these lines representing the amount of steam in each cylinder. This is only true when all the steam which is exhausted from the high pressure cylinder appears in the low pressure.

By measuring a large number of cards from engines of various kinds, it was found that in ordinary single-valve engines with piston speed of about 600 feet per minute, with tight valves and

pistons, without steam jackets, 90 per cent. to 95 per cent. of the steam exhausted from the high-pressure cylinder appeared in the low. With steam jackets this is increased to 95 per cent. and 100 per cent. Knowing this, it is easy to make allowance for it in getting the cylinder ratio.

If the cylinder ratio is given instead of the ratio of expansions, an assumption will have to be made after drawing the high-pressure expansion curve, for, until we know to what point the compression will be carried in the high-pressure cylinder, we cannot locate the point on line BK, from which to start the low-pressure expansion curve. The point E is located by measuring from C a distance equal to $\frac{BK}{R}$, R being the ratio of the cylinders. So we estimate the back-pressure line of the high-pressure card and draw the compression curve. If this estimate is in error it will be shown as soon as the low-pressure expansion curve is drawn, and with this as a guide the compression curve can now be drawn correctly and then a new expansion curve for the low-pressure card.

If it is desired to divide the range of pressures in the two cylinders so as to give about the same amount of work in each cylinder, the line GL must be drawn so that the areas of the two cards are to each other as the inverse ratio of the cylinders.

In assuming data from which to draw a set of cards, there are so many variable quantities that one method of procedure cannot fit all cases. The modus operandi in each case will, of course, depend upon the conditions which are assumed as a basis upon which to start. But if this general scheme is fully understood, there is no trouble in drawing cards to suit any case, when enough data is given to make the problem determinate.

The set of cards shown in Fig. 2, is drawn to show the use of this scheme as applied to cards for a triple-expansion engine.

After drawing the fixed lines as before, the high-pressure and low-pressure expansion, and the low-pressure compression curves are drawn, continuing the last two curves up to the line BK. The intermediate pressure card is left out of consideration at first. The point G is located as before, and then the back-

pressure line and compression curve of the intermediate-pressure card can be drawn. The expansion curve for this cylinder can be drawn from either end. If a certain amount of "drop" at release is desired, the curve will be drawn from the lower end; if a certain cylinder ratio is desired, it will have to be drawn from the upper end, the ratios of the lines BK, CE and MN being the cylinder ratios. The completing of the diagram is the same as for the compound.

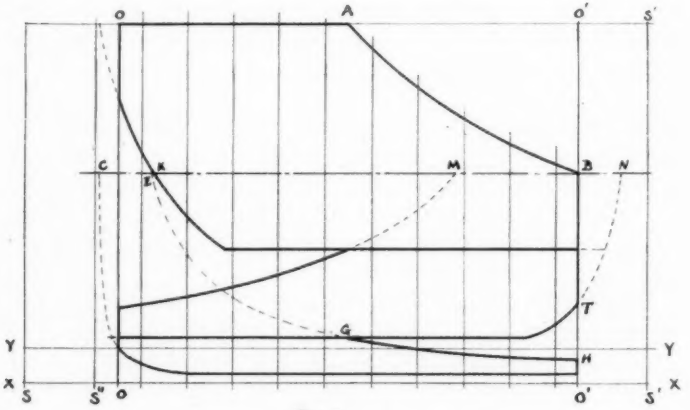


Fig. 2

If instead of the ratio of expansion, the cylinder ratios are given, the compression curve of the high-pressure cylinder will have to be estimated as was done with the compound-engine cards.

In drawing these cards, it has been assumed that the receivers are large enough to make the back-pressure lines of the cards parallel to the atmospheric line.

The following method of combining indicator diagrams was explained in a paper read before the American Society Mechanical Engineers by my father; it is contained in vol. xv, page 404, of the Transactions.

The method which is shown in Figs. 3, 4 and 5 consists in reducing the lengths of the cards so that they are to each other

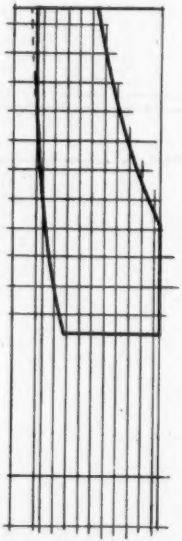


Fig. 3.

Fig. 4.

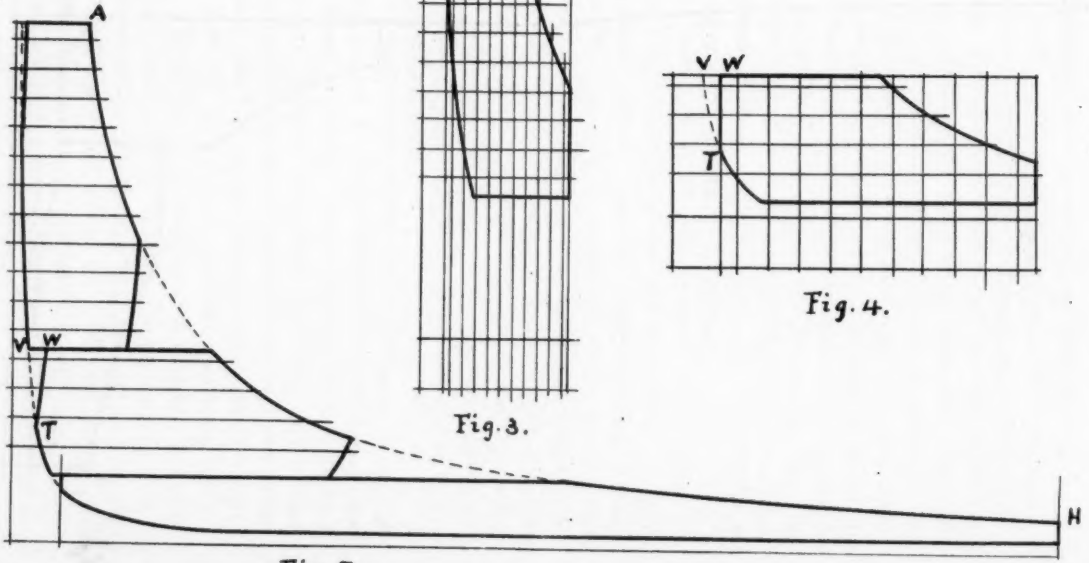


Fig. 5.

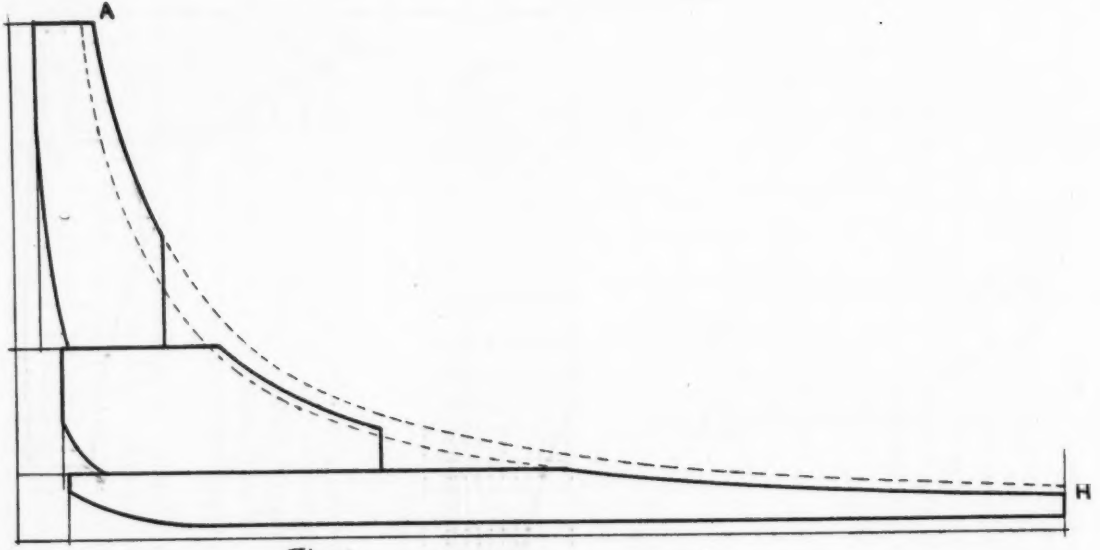


Fig. 6.

as the cylinder ratios. If it is desired to refer them all to the low-pressure card, as is generally the case, the compression curve of that card is continued up to the top of the high-pressure card. Then the other cards are placed so that their compression curves match exactly this new compression curve, care being taken that all horizontal lines through the cards are the same length as before. An easy way to do this is to draw horizontal lines through the cards, as in Fig. 3, at intervals of say 10 pounds. On these lines measure from the compression curve, or this curve produced as TV, Fig. 4, to its intersection with the other side of the diagram, and transfer this length to the corresponding abscissa of the combined card. The line TW can then be located, and the diagram is complete.

These cards were originally constructed on the hypothesis that there are no losses, except by free expansion, into the clearance spaces at admission and into the receivers at release. These are the *only* losses which appear on the combined diagram, and it will be observed that the expansion curve is continuous, fitting the expansion curve of each diagram exactly. This will always be true, no matter how widely the clearances in the different cylinders may vary. With diagrams combined in this way, it is easy to see where the losses are, and to measure accurately their amounts.

Fig. 6 shows these same cards combined in the usual way of reducing the cards to their proper length and then superposing the clearance lines. It can be seen at a glance how crude this method is, for here we have cards which are constructed on the hypothesis that there is no loss or gain of steam from one cylinder to the other, and yet an expansion curve from the high-pressure card does not fit either of the other expansion curves at any point. There is nothing really wrong with this method, for the cards are just as true in this form as they were before; but the only object of combining them is to get some additional information from them in regard to the continued expansion from one cylinder to another, and to ascertain what percentage of the ideal diagram they realize. As neither of these things is

shown with any degree of accuracy, practically nothing is accomplished.

To show this more clearly, the expansion curve is continued from the high-pressure card to the end of the low-pressure card, and one is also constructed from the low-pressure to the top of the high-pressure. Neither of these curves fit the expansion curves of either of the other cylinders at any point.

In engines having small and uniform clearances, this method gives fairly accurate results, but in marine work and all other work where the clearances are necessarily large it seems to be a waste of time to use a method which is so much at fault.

ELECTRICAL PROPULSION FOR TORPEDO BOATS.

By Prof. W. F. Durand, Member.[1]

The application of electricity to marine propulsion has in recent years attracted the attention both of electrical and marine engineers, and the successful operation of the electric launches at the World's Columbian Exposition in 1893 gave to many strong hopes that the field of such application might be immediately widened to include small craft of all descriptions and for all purposes, and that the day was not far distant when even large craft as well, the liner, the freight steamer and the warship, would all derive their propulsive power from energy stored in the electric form. It was early recognized, however, that energy embodied in storage batteries is excessively expensive in weight as compared with energy embodied in coal, and furthermore that electric motors are usually heavier for the same power than the lightest types of steam engines. These facts introduced a prompt limitation to the extension of electric propulsion, especially to cases where high speed or long endurance was desired.

In a paper published several years ago * the author showed the limitations and presented the possibilities of electric propulsion as given by the practice of that day. It may not be without interest to reconsider the same subject briefly, and to note what advances have been made since the publication of that paper. Especially may this be suitable at the present time in connection with the appearance of an article in the last number of the Journal by Mr. C. T. Child on the same subject.

The data which are used in the latter article and which are made the basis of the case as presented, seem to be considerably beyond current American practice, and undue expectations may perhaps be awakened regarding the readiness with which such results could be realized.

* Cassier's Magazine, June, 1895.

In regard to the fundamental values assumed for the torpedo boat it may be said that the power is perhaps a trifle low for the displacement and speed, and the fraction of weight available for machinery and propulsive equipment rather high, both tending, of course, to make a better case for the electrical equipment. These differences, however, are not of particular importance, for the question of the availability or otherwise of an electrical equipment rests on considerations of a more serious and fundamental character.

Let us then proceed to a comparison between an electrical and a steam propulsive equipment, using in addition to the data taken by Mr. Child, such additional safe values from modern engineering practice as might naturally be made the basis of a business contract. We need first to specify units of *power* and *work* relative to which the comparison may be made. For these we shall take respectively the *horse power* delivered to the screw shaft, and the *horse power per hour* delivered to the screw shaft.

For the steam equipment we may allow 2.5 pounds coal per H.P. per hour on the shaft. This will occupy about .05 cubic feet bunker space. For the total weight of steam equipment, including engines, boiler and auxiliaries all in steaming condition, we have values ranging from 40 pounds to 70 pounds per power unit on the shaft. Of this amount the engine-room weights furnish rather less than one-half and the boiler-room weights rather more than one-half.

Turning now to the electrical equipment, we must examine the weights of batteries and motor for the same units on the shaft. Taking first the batteries, we must distinguish two questions:

(1.) How much battery is necessary in order to actually attain a certain desired power, aside from the question of endurance?

(2.) How much battery is necessary in order to embody a given amount of energy, aside from the question of how rapidly it is used or how much power is developed?

The two questions are not independent, and must be examined together.

In Fig. 1, AB shows the nature of the relation between the

total capacity of a storage battery and the time of discharge, while *A C* shows the corresponding value of the discharge current. Beyond three or four hours the total capacity more slowly increases with the time, as shown, while for a shorter period the total amount which can safely be taken from the cells quite rapidly falls off. The power which can be developed depends, then, simply on how rapidly the cells can be discharged, and is, of course, proportional to the discharge current, as shown by *A C*.

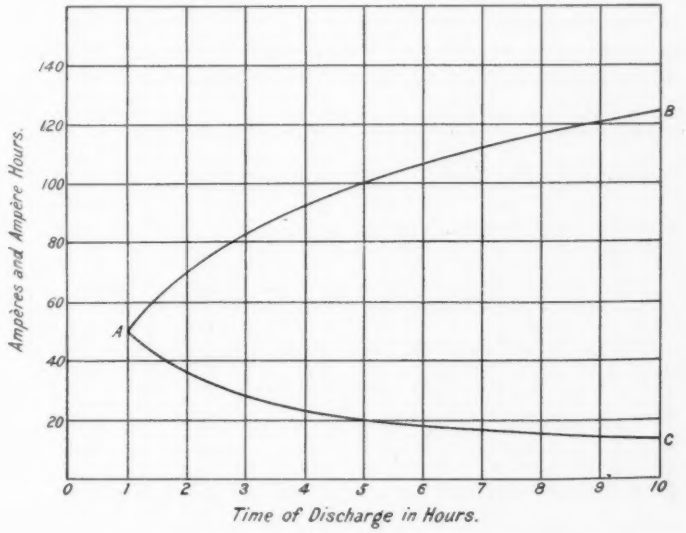


FIG. 1.

Capacity in ampère-hours and corresponding current in ampères for varying time of discharge. For relative purposes the capacity at five-hours' discharge is taken at 100 ampère-hours.

The limit to the development of large power from a small battery is, therefore, the increasing danger of damage to the cells resulting from excessive rates of discharge, and the rapidly decreasing time during which the power is available. The normal discharge period is usually taken at from eight to ten hours, but with care it may, with the best types of cells, be safely decreased to four or five hours. For a few moments the discharge current

may even be increased far beyond the values corresponding to these periods, but for what may be termed continuous conditions a rate corresponding to discharge in four or five hours is about the maximum usually employed.

If we take now the weights of the leading American storage cells as built for stationary purposes, and derive for the various rates of discharge the weight per *horse power per hour* of battery output, and of weight per *horse power* of output, we shall find values as represented by *A B*, Figs. 2 and 3, respectively. The increase of weight per work unit as well as the decrease of weight per power unit, as the time of discharge is decreased, are both clearly shown by the diagram. In these cells the weight of the

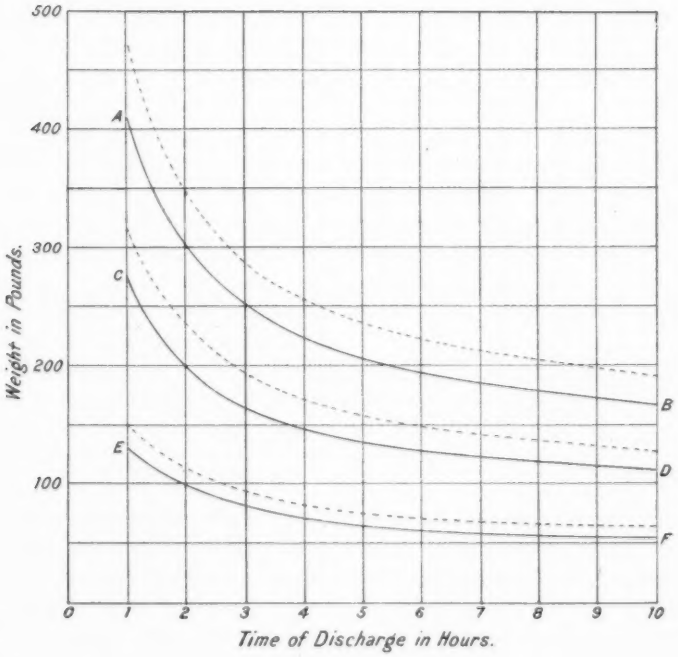


FIG. 2.

Weight of batteries per H.P. per hour for varying time of discharge.

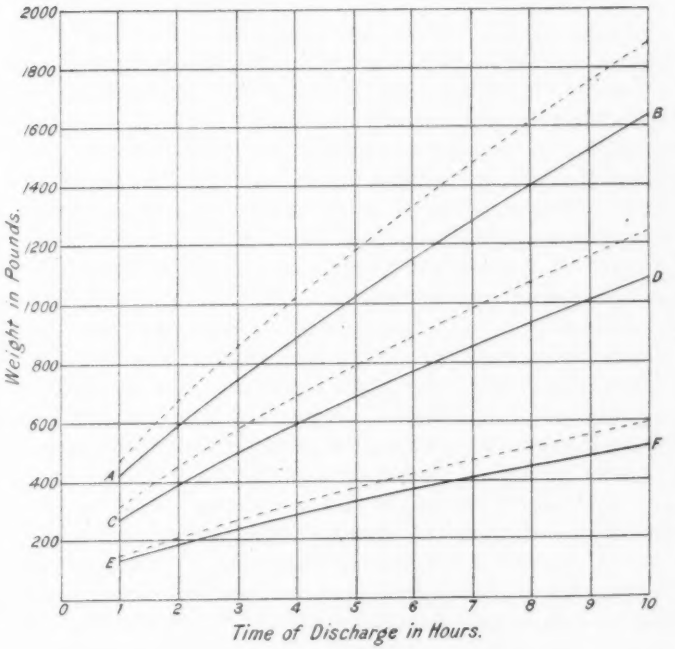


FIG. 3.

Weight of batteries per H.P. for varying time of discharge.

lead elements is from 50 to 55 per cent. of the cell complete with acid and lead lined wooden tank. In a somewhat lighter form of construction for cells of the same type the weight of the lead elements is about 65 per cent. of the cell complete, and the latter ranges at about two-thirds of the values shown by the curves, *A B*. These lower values are shown by the curves *C D* on the same diagrams. These figures and diagrams show what may be expected from commercial cells at present on the American market. As to possible reductions in the weight of this type of lead cell, the future alone can determine. It is a significant fact, however, that these cells as built at the present day, are considerably heavier than those on the market a few years ago. This

seems to indicate that for purposes of durability, reliability and continuity of operation, the heavier type of construction is preferred where the additional weight is not a special disadvantage.

Turning now to the results given by the report of the French tests of automobiles, as referred to by Mr. Child, we find an entirely different range of figures. In these cells the normal period of discharge is taken as five hours, and the figures for power output and capacity refer fundamentally to this period. At the same time the capacities for a discharge current double and half the normal value are also stated. These correspond to periods of about two and eleven hours. Between these limits the resultant capacity curve plotted on time agrees fairly well with similar data derived from American practice, and the curve $A\,B$ of Fig. 1, which represents a series of mean values drawn from a considerable range of recent American data, may probably be taken as representing satisfactorily the relative capacity curve for the automobile battery as well.

In this battery the weight of the lead plates is about 70 per cent. of the cell complete. For the latter, the weight per horse-power output for a five-hour discharge is 321 pounds, and per horse power per hour output, sixty-four pounds. It will be seen that these figures are from about one-half to one-third those for the cells on the American market. They are represented by the curves $E\,F$ in Figs. 2 and 3. As to how far it would be safe to expect that this lighter type of construction would be suitable for marine propulsion, it is difficult, from the description given, to form a satisfactory opinion. Until more evidence is forthcoming, however, their suitability to such uses may be fairly open to some doubt.

With regard to the space occupied, and basing the total out-put on the five-hour discharge, we find for the American cells a space of from 1 to 1.4 cubic feet per horse-power per hour output, while for the lighter automobile cells the space required is about .5 cubic foot, or about in the same proportion for space occupied as for weight.

It will be noted that the above figures for batteries all refer to

output. Assuming a motor efficiency of .87, we may reduce to similar units on the shaft by dividing by this ratio, an operation which will increase the several figures by about 15 per cent. of their former values. A uniform efficiency as high as .87 is more than can be expected, especially for the extreme conditions, but the error favors the electrical equipment, tends toward simplicity of treatment, and is not significant for the purpose in view which is not so much to take account of all secondary influences as to show the general character of the results to be expected under the various suppositions made. In Figs. 2 and 3 the increased weights are shown by the dotted lines. For the space occupied the figures will be from 1.15 to 1.60 cubic feet per H.P. per hour for American batteries and about .58 cubic foot for the automobile battery.

Turning now to the motors, we find a wide variation in figures. During the past five years some advance has been made in the reduction of weights, and, taking values representing the best actual practice, we find from 30 to 50 pounds and upward per H.P. on the shaft. The minimum figures correspond to revolutions per minute of not over 400 or 500 for the larger sizes. Some further saving might still be made by an increase of revolutions, but such saving is limited, for the weight of motors by no means decreases as the revolutions increase. Heating in the armature and poles, and structural considerations connected with the necessary space for insulation, etc., place an early limit on the reduction of weight by increase of revolutions. As suggested by Mr. Child also, some further reduction might be made by more extended use of laminated iron in the field, but it may be fairly questioned whether so large a reduction as that implied in the figures given in his article could be hoped for. In any event, so far as the author is aware, motors weighing only 16 pounds per unit of horse power output are not the subject of current design, they are not on the market, and it is doubtful if reliable builders would care to guarantee weights much below the minimum stated above. If we take the best of present-day practice as represented by motors actually built and ready for use, we shall not be able to go much below 30 pounds per horse-power on the shaft for such motors as would be suitable for purposes of marine propulsion. We will, however,

assume 25 pounds as presumably obtainable at the present time by special design.

Taking the figures given above it results that for equal amounts of work delivered to the shaft, storage batteries, on the basis of a five-hour discharge, weigh from thirty to nearly one hundred times as much as coal, and occupy from ten to thirty times as much space.

For the same power delivered to the shaft, the electric motor will weigh somewhere about one-half the total weight for a steam boiler and engine, and rather more than the engine-room equipment alone.

It is quite evident that in an electrical equipment the weight of battery will be the chief item, and that the necessary weight will be determined by the maximum power required and by the safe rate of discharge at which this power may be developed.

If the maximum speed of the boat is to be considered as 22 or 25 knots, then in order that such a term may have any significance in a tactical or naval sense, it should be possible to maintain this speed for at least one hour and, preferably, more; and it would seem unwise to use in the development of such a speed for a period of an hour or more, a discharge current higher than that corresponding to a four-hour complete discharge. It is true that a boat thus equipped could make rushes of short duration at a much higher rate of speed, but to be of tactical value their safe duration should extend beyond periods of a few minutes. It may be here noted that in the report of the French Commission on automobiles, the maximum discharge considered as allowable for anything beyond momentary rushes of current is that corresponding to complete discharge in about $3\frac{1}{4}$ hours, a current one-third above the normal for a five-hour discharge. A further limitation arises from the rapid loss of safe total output at excessive rates of discharge, so that the relative endurance rapidly decreases as the discharge current is increased.

Thus, according to the law indicated in Fig. 1, a doubling of the discharge rate for a four-hour period will reduce the endurance to one-fourth its value, or to about one hour. The qualities

of a torpedo boat and the conditions which she should fulfill are, of course, largely matters of opinion; but taking into consideration questions of tactics and safe endurance, it would seem as though a requirement of full speed for one hour at a discharge rate not exceeding that for a four-hour endurance, or a possibility of full speed for four hours, is little enough to require of a boat intended to meet the probable exigencies which may attend the operation of such craft. Taking the values from Fig. 3 for a four-hour discharge, we find that for a 140-ton boat, with 2,000 shaft H.P., the weights required would be, for American batteries, from 1,400,000 to 2,000,000 pounds in round figures, and for the automobile battery about 650,000 pounds. In any case the weight required is several times the total displacement of the boat, and hence entirely out of the question. For 1,500 H.P. the weights would be three-fourths of the above amounts, and hence equally unattainable.

It is thus clear that the requirements as laid down, and as they might naturally be taken, having in view the results attained by steam equipment, are entirely out of the question. Even in the case of the automobile battery, regarding the suitability of which we may still reasonably doubt, the weight required for batteries alone is about twice the total displacement of boat. We may then naturally, as does Mr. Child, approach the question from another standpoint, and, taking a certain amount as disposable for motor and batteries, investigate the possibilities.

To this end let us assume that the motors are to be rated normally for the power which would be developed with the two-hour discharge current. They could then stand, for short periods, increased rates of discharge up to that corresponding to a one-hour endurance. This would provide for the possibility of short rushes at excessive rates of discharge and developed power, and the motors would, of course, be more than ample for lower rates and longer periods of endurance. For a two-hour discharge current, according to Fig. 3, American batteries will weigh from 440 to 660 pounds per H.P. on the shaft, and the automobile battery about 210. Adding, say twenty-five pounds

for motor, we should have respectively the figures 465 to 685, and 235.

Out of the total displacement of 140 tons we will take, for our present purpose, the same amount as that assumed by Mr. Child, viz: 201,000, as disposable for motors and battery. Dividing this weight by the above figures, we should find for the rated motor powers, respectively, 293 to about 430 and about 850. The corresponding motor weights would be, respectively, 7,325 to 10,750 and 21,250. The balance available for battery would be, respectively, in round numbers, 194,000 to 190,000 and 180,000, and on the basis of the laws expressed in Figs. 1 and 3 we might expect results somewhat as given in the following table:

Time of complete discharge.	Heavier American Battery.			Lighter American Battery.			Automobile Battery.		
	Power.	Speed.	Endurance.	Power.	Speed.	Endurance.	Power.	Speed.	Endurance.
1	412	15.2	15.2	618	17.2	17.2	1,320	21.0	21
2	290	13.6	27.2	435	15.5	31.0	929	19.5	39
3	228	12.7	38.1	342	14.4	43.2	730	18.0	54
4	190	12.0	48.0	285	13.5	54.0	609	17.0	68
5	164	11.4	57.0	246	12.9	64.5	525	16.4	82
10	103	9.9	99.0	155	11.2	112.0	330	14.1	141
24	52	8.0	192.0	78	9.0	216.0	167	11.5	276

A boat with capacities as given by these figures may be made use of in a variety of ways, but even in the most favorable case such a craft is not a torpedo boat. So far as the use of the results from the report of the French Commission on automobiles is concerned, the chief difference between these figures and those derived by Mr. Child is in the possibilities at excessive discharge rates. Experimental information on this point does not seem to be given in the report. The normal rate of discharge was considered to be that for a five-hour period, for which the figures as taken from the report have been given above. In addition, statements were made regarding the capacities at double and half the

normal rates of discharge, as previously noted. In the actual tests as shown by the time of run and by the graphic logs of the discharge currents, the mean rate was only slightly above the normal, though momentarily it rose to values two or three times as great. The general law connecting safe capacity with time of discharge, as shown in Fig. 1, and particularly for very small periods, has been already referred to; and extending such general law to the lighter automobile cell, it follows that the expectation of 2,000 H.P. for one hour, based on the actual performance of about 500 for five hours, is far beyond what is likely to be realized. This would require a safe capacity for one hour of about 80 per cent. of that for five hours, an assumption requiring the same general rate of decrease between five hours and one hour as is usually found between eight or ten hours and five hours. Available data shows that this expectation is far from any probable realization.

Even if the automobile battery were found well suited to marine propulsion and the full results as derived by Mr. Child were obtainable, the resulting boat would be of problematical value, for the utility of a torpedo boat with an endurance of only 25 miles at full speed may fairly be called in question. What should we think of a like torpedo boat with steam equipment developing 2,000 horse-power, and carrying only about two tons of coal instead of twenty or thirty?

Let us now turn briefly to the possibilities under steam equipment with the same weights available for propulsive purposes. Taking the total weight of 213,000 pounds, as assumed by Mr. Child for motors, batteries and controlling devices, we will first assume 30 tons of coal. This leaves 145,800 pounds available for steam machinery. Without going to the extremes of light construction this would provide for the development of from 2,500 to 3,000 I.H.P., giving from 2,200 to 2700 H.P. on the shaft. Taking again only 10 tons of coal as corresponding to trial conditions, we should have 190,600 pounds available for steam machinery, which would provide for the development of from 3,000 to 3,800 I.H.P., giving from 2,700 to 3,400 on the shaft. These figures correspond closely to the latest Navy Department designs

for torpedo boats, where, with 150 tons displacement, 3,000 I.H.P. are to be developed on 178,600 pounds, giving practically 60 pounds per I.H.P. Merely as a matter of comparison with the electrical equipment it would not be unfair to reduce the coal to the amount necessary for one hour at full speed. If short endurance is admissible in one type of boat it should not be denied the other. This would reduce the coal to about four tons, leaving 204,040 pounds for steam machinery, on which from 3,400 to 4,000 I.H.P. could be developed, giving from 3,000 to 3,600 H.P. on the shaft. Of course no one would think seriously of a boat with so small a coal supply, but for comparative purposes it serves to show how wide is still the gap between the possibilities with steam and electrical equipment. With the former we readily develop three times the power possible with the latter, even under the best conditions furnished by the automobile batteries, and from six to eight times the amount under the best conditions given by the standard batteries on the American market. On this point it should be said that these batteries are intended for stationary use, and are not designed or built with a particular view to the saving of weight. With the latter point in view, doubtless a lighter type of construction could be developed, and the figures for the French automobile battery reproduced. The durability and adaptability to marine propulsion of such a battery would still be an open question, and only to be settled by the appeal to experience. All this, however, as we have seen above, would still leave the electrically-driven torpedo boat far from a reality.

The subject of cost should also be noted in connection with the general comparison between these two modes of torpedo-boat propulsive equipment. Mr. Child makes the statement that the cost would be about the same in either case. It is hard to find prices which verify this statement. Steam machinery complete may be built for from $20 to $25 per I.H.P., or from say from $22 to $27 per shaft horse power. The electric motors, including switches, controlling devices, etc., will very nearly cover these figures, leaving the first cost of the batteries practically without an offset in the steam equipment.

Recent net quotations on American storage batteries were on the basis of about $9 per 100 ampère hours for a five-hour discharge. In large quantities we might expect a reduction, but probably not below from $6 to $7 for the same unit. This would correspond to from $24 to $28 per H.P. hour on the shaft, or from $120 to $140 per H.P. on the shaft for the five-hour discharge. Taking for commercial American cells the possibilities in the present case at about 200 H.P. for five hours, or 1000 H.P. hours, we should have for battery alone say $25,000. Taking the motor as rated at 350 H.P., its cost would be, perhaps, about $7,000, thus giving $32,000 for the electrical equipment. A 350-H.P. steam equipment complete could be provided for from $8,000 to $10,000.

Regarding the cost of energy in storage batteries it appears that, taking into account the losses incident upon the various transformations through which it is passed, that mechanical energy delivered to the shaft by a motor from a storage battery will cost nearly twice as much in pounds of coal at the steam engine which charges the cells, as it would if delivered direct from the engine to the shaft. That is, for equal amounts of work on the shaft, electrical propulsion will require the initial consumption of nearly twice as much coal as with the steam engine coupled direct to the screw shaft, the two engines concerned being of about equal efficiency.

There are still other questions which may affect the application of electricity to torpedo-boat propulsion, such for example as the need of protecting both cells and motors from salt water, the need of closing in the cells so as to prevent spilling of the acid due to rolling, questions of durability, repairs and renewals, questions relating to the dependence of a boat upon a generating set as a base of supplies for recharging the cells, etc. These are, however, of secondary importance in comparison with the fundamental question of what can be done, granting that all secondary questions are supposed to be favorably answered. The present paper is concerned with this fundamental question rather than with those of secondary importance. All special discussion of torpedo-boat tactics or of the special suitability or otherwise of

limited endurance to torpedo-boat service have been also left aside as unnecessary to the main purpose of the paper.

There are, of course, many special advantages connected with electrical propulsion, such as relative noiselessness and freedom from vibration, absence of smoke or flame, safety from disastrous explosion, instantaneous readiness for use so long as charged, etc., and it is to be most strongly regretted that the limitations are of such a character as to render the possibility of availing ourselves of these features dependent upon a reduction in the weight of storage cells which at present seems hopelessly beyond reasonable expectation. When it is realized that the light French automobile cell weighs some three hundred times as much as coal for equal energy stored, and some thirty times as much for equal amounts of work at the shaft, it is clearly apparent that so long as these relations hold the storage cell cannot hope to displace coal for marine propulsion except in those cases where moderate speed and short endurance are not objectionable. To our present-day judgment it would seem that if energy stored in the electrical form is to rival in compactness that stored in coal, it will require a development along some line entirely different from that represented by present-day storage cells.

What developments in these lines the future may hold for us the event alone can determine, and should the day soon come when electricity can be satisfactorily and efficiently employed for the attainment of the highest results in marine propulsion, probably none will be more ready to welcome the change than those who see in its present-day limitations an insuperable bar to its use at the present time.

AUTOMATIC STOKERS FOR MARINE USE.

The proper and scientific method for governing the combustion of fuel unquestionably has absolute regularity of supply and distribution, both of fuel and air, as a primary feature. Wherever man is alone depended upon to control continuous operations of this kind there will always be found a large though varying per cent. of loss due to carelessness, forgetfulness, ignorance, fatigue or indolence, singly or in combination, and it is for this reason that engineers have always looked to automatic devices to eliminate as far as possible these losses. If by mechanism he can reduce the number of separate operations to be performed by a fireman, he reduces equally the chances of failure to carry out the functions properly.

In the burning of coal in boiler furnaces skillful and scientific firing is always attended by difficulties which increase with the quantity to be burned per square foot of grate as well as with the character of the fire rooms. Thus, on shore, where ample space is allowed for boilers and furnaces, and the ventilation good, the work is far easier to perform well than it is in the "hell hole" of a torpedo boat. Practically, under forced-draft conditions afloat, firing only approximates the ideal, and it is seldom that either the supply of fuel is of proper frequency and quantity; generally the fault being the greater quantity at a charge and at too long intervals. Attention to the supply, as ordinarily practiced, also involves losses through this interruption of the cycle of combustion and adds other bad features by the surplus volume of cool air admitted through the fire doors.

The inventions for conducting "automatic stoking," therefore, have not been few, and probably their adoption in many land plants came through a desire to economize in reducing the number of employees rather than in order to obtain better results from the fuel burned. Here, almost any practical device could

be experimented with, but up to recently there appeared always to exist features which rendered the appliances wholly inapplicable to use on shipboard where furnaces are of such limited height and width, and the angle of grate with the horizontal line so variable, owing to the rolling of the ship.

The "Marine Review" of December 15th, 1898, called attention to the fact that the Zenith Transit Company, of Duluth, were to instal automatic stokers (The American Stoker) on their new big 7,000-ton freight steamer in connection with Babcock & Wilcox boilers, and inquiry has led us to present the principal features of this stoker here, prior to the actual experience they are to have, and dependent upon which criticism is reserved. Merely as a possibility, the appliance is interesting to marine engineers, and the obviously objectionable features or faults are also left to individual study. In presenting the following description of the apparatus, taken from the company's illustrated circular, attention only is called to the cross section of the fire (understood by following the description carefully), and to the matter of cleaning fires; also to loss of fresh water by exhausting steam from the motors into the ash pan, this latter no doubt being easily obviated in marine installations. In this particular installation three of these stokers are to be placed in each furnace, the magazines being each 24 inches wide, and a dead grate of 18 inches separating each magazine from its neighbor; also a dead grate of 12⅝ inches between the side of each outer magazine and the side of the furnace. Of course each magazine is the full length of the furnace.

Mechanical stokers and patent furnaces are divided, by reason of the principle upon which they operate, into two classes: those "overfeeding" the coal and those "underfeeding" the coal. The former are new adaptations of the principle used in the plain grate-bar furnace. The weakness of common grate-bar practice is recognized from the fact that, following the natural draft, the greatest quantity of air is admitted through the grate at points where the coal bed is thinnest, whereas the most air is needed where the coal bed is heaviest. The coal thrown on a hot fire releases its gases very quickly, and if there be an insufficient quantity of air

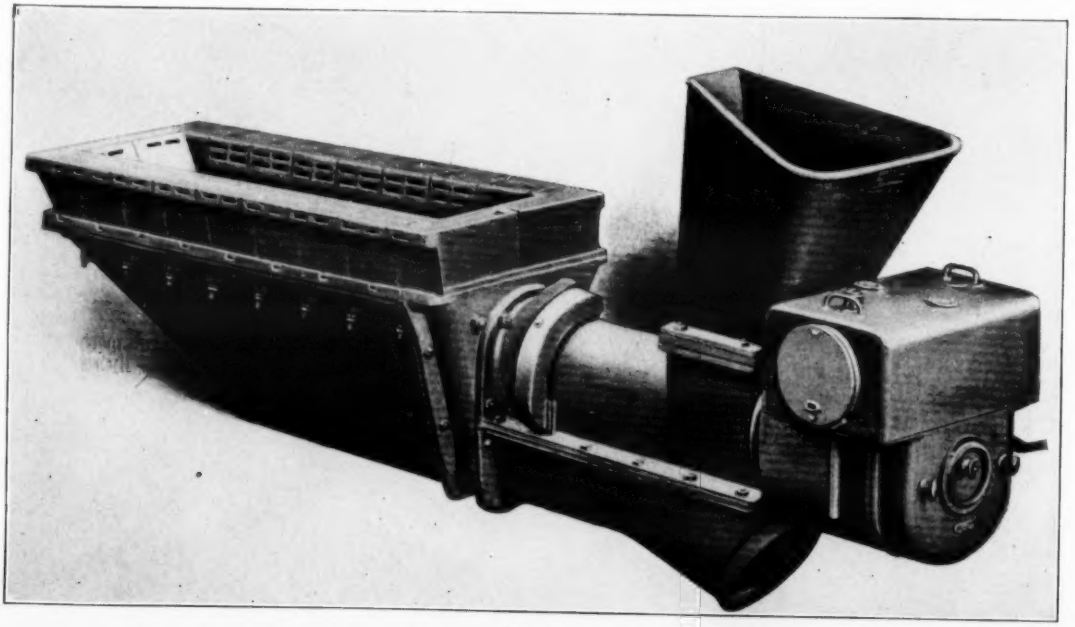


FIG. 1.

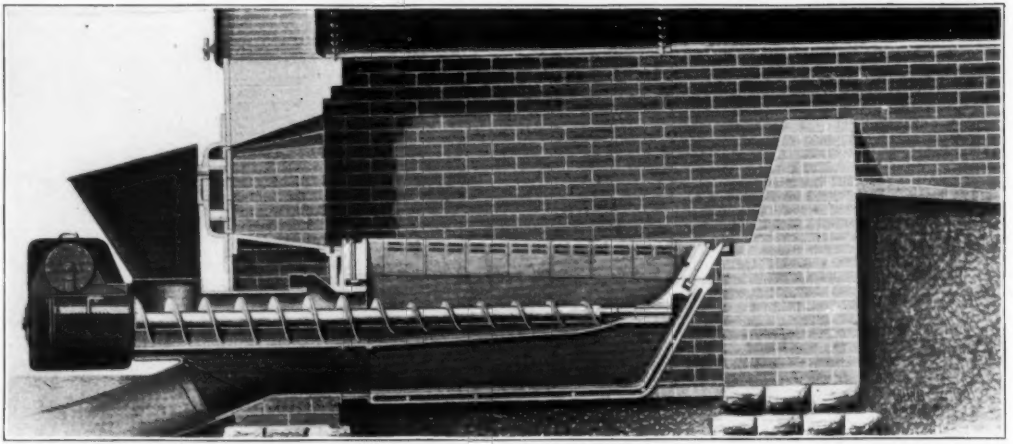


FIG. 2.

at this point of release, these gases pass off unconsumed, causing smoke. The "overfeed" stokers and furnaces seek to overcome this by mechanically feeding the coal in small quantities in such manner as to evenly distribute the coal, thus causing a more even admission of air.

The American Stoker is of the "underfeed" class, and is here illustrated (Fig. 1), completely assembled and ready for installation. Immediately beneath the coal hopper, and communicating with it, is the conveyor pipe; this in turn communicating with the coal magazine. A screw conveyor or worm is located in the conveyor pipe and extends the entire length of the magazine, as shown in Fig. 2. Immediately beneath the conveyor pipe is located the wind box, having an opening beneath the hopper. At this point is connected the piping for the air supply, furnished at low pressure by a blower. The furnace end of the wind box opens into the air space between the magazine and its outer casing. The upper edge of the magazine is surrounded by tuyeres, or air blocks, these being provided with openings for the discharge of air, inwardly and outwardly.

Each stoker is driven independently by a small steam motor, located immediately in front and beneath the hopper. The motor has a simple reciprocating piston. Its piston rod carries a crosshead, which, by means of suitable connecting links, operates a rocker arm having a pawl mechanism, which in turn actuates a ratchet wheel attached to the conveyor shaft. The stoker is thus entirely self-contained and complete in itself, and consequently there is no danger of the driving and feeding mechanism (the only working parts) ever getting out of alignment. The rate of feeding coal is controlled by the speed of the motor, this being effected by the simple means of throttling the steam in the supply pipe to the motor. The shields covering the motor effectually protect the mechanism from dirt and dust.

No special furnace setting is required. It is only necessary to change the location of the rear bearing bar to suit the length of the stoker, and to introduce the conveyor pipe through the front. The stoker rests on the front and rear bearing bars; the space between sides of stoker and side walls is filled with iron plates,

termed "dead grates." Steam is carried to the motor by a ¾-inch steam pipe. The exhaust steam from the motor is discharged into the ash pit.

The coal is fed into the hopper, carried by the conveyor into the magazine, which it fills, "overflows" on both sides, and spreads upon the sides of the grates. The coal is fed slowly and continuously, and, approaching the fire in its upward course, it is slowly roasted and coked, and the gases released from it are taken up by the fresh air entering through the tuyeres, which explodes these gases and delivers the coal as coke on the grates above. The continuous feeding gives a breathing motion to this coke bed, thus keeping it open and free for the circulation of air.

Every pound of coal fed into the hoppers passes through this gas-making process, and there is no loss of coal through grates, by reason of the use of dead grates in the furnace in place of open grate bars. The non-combustible is taken from the furnace, necessarily from the furnace doors, in the shape of vitrified clinker. There is practically no soot.

Ability to feed the finest of slack coal and also handle lump coal is claimed, as any lump that can be fed into the hoppers will be crushed by the conveyor, there being provided a set of teeth, placed at the mouth of the conveyor, against which the coal is squeezed and broken.

Using the grades of coal found in and east of the Pittsburg coal district, fires need not be cleaned oftener than once every twelve hours. Ohio, Indiana and Illinois coals of low grade generally require cleaning once in eight to ten hours. All depends on the quantity burned.

The non-combustible takes the form of vitrified clinker, deposited in a form like a cake on the grates next the wall, being "shed" to one side by the constant upward feeding of the coal. One open grate against each wall admits air and steam from below (the steam being the exhaust from the motor), and this prevents the clinker sticking to the walls.

To clean, a slice bar is run along over the grate, the clinker raised and drawn out with a hook. The central part of the fire is never disturbed. The constant feeding does all the stoking

necessary. The fire doors are never opened except when cleaning, thus avoiding the cold inrush of air, so damaging to the boiler tubes and sheets.

The exhaust steam from the motor is discharged into the ash pit. One fireman can readily handle four stokers, shoveling his own coal. With mechanical coal carriers along the front of the boilers, one man can handle from twelve to fifteen stokers.

It has been found that the ordinary steam jet, so often used in connection with smoke-preventing devices, takes from 10 to 15 per cent. of the steam made by the boiler. The steam used in actuating the motor on this stoker is stated to be less than twelve one-hundredths of a horse-power, and adding to this the steam used in the actuating of the blower, the total charge for the actuation of a stoker equipment can be estimated at about 1½ per cent. of the steam made, and adding to this the reduced cost of firemen for handling the coal, the total cost of the actuation of these stokers is far below that of ordinary hand firing.

The practicability of any stoker depends upon its cost of maintenance. No mechanical part of the American Stoker is subjected to intense heat. The tuyere blocks alone come in contact with the fire, and these are protected by the constant circulation of air. These blocks are common iron castings, weighing but twenty-four pounds each, and are readily replaced or renewed.

The conveyor shaft is a 2¾-inch steel shaft, on which are strong "flights." These flights, by their decreasing diameters, distribute the coal equally over the entire width and length of the furnace. The entire mass of coke above the tuyere blocks and over the side grates is ignited. The depth of the bed of burning coke above the tuyere blocks is from 14 to 18 inches. The air enters the stoker from the front beneath the hopper, passes through the wind box and discharges through the tuyere openings. The discharge of air into each stoker is regulated by a wind gate located at the mouth of the wind chamber.

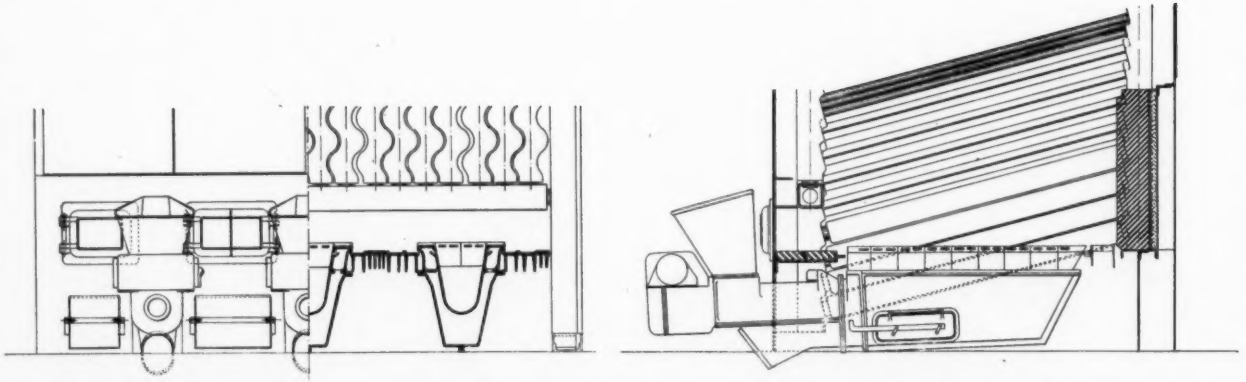
In an average setting the stoker mechanism extends 33 inches in front of boiler front.

While the presence of smoke at the stack indicates imperfect combustion, yet it must not be taken as an evidence of great

loss. A stack may be smokeless, and yet the dilution of the gases, by reason of too great a supply of air at the furnace, may be such as to be causing a great loss.

The principle upon which the American Stoker operates, practically reducing the coal to gas and coke, and passing all products of combustion through an incandescent coke bed, is a guarantee of freedom from smoke and soot.

The tendency exists in all ordinary furnace practice to burn "blow holes" in the fire. The greatest amount of air will enter through a common grate at a point where the fire is thinnest, and at which point the least amount of air is required; while at the point where the bed of coal is thickest, where the greatest amount of air is required, the least is supplied. The continuous feeding action of the stoker in a remarkable degree overcomes this natural difficulty. The air being supplied under mild pressure of from 1 to 1½ ounces, passes through the burning coal, and is brought intimately in contact with the incandescent coke.



THE BABCOCK AND WILCOX WATER-TUBE BOILERS FITTED WITH AUTOMATIC STOKERS FOR THE ZENITH TRANSIT STEAMER.

TEST OF A DIESEL MOTOR.

Supplementing the valuable paper of Col. E. D. Meier on the Diesel Motor, published in the February, 1898, number of the JOURNAL, we here give a synopsis of a report as recently printed in the "Engineering News," by Professor James E. Denton of the Stevens Institute of Technology, presenting the principal results of a series of economy tests of a Diesel motor, rated at 20 brake H.P., using various kinds of oil as fuel. The motor is one of the first made for the market in Germany, and is the first that has been brought to this country. It was erected at the Electrical Exhibition held last spring in New York city, where it drove an electric-light plant for five weeks. It was then erected for the purpose of the tests at No. 24 West street, New York city. The results confirm those obtained from similar engines in Germany, and are worthy of record as marking a long step forward in the economy of oil engines.

DESCRIPTION OF MOTOR.

The motor has one main cylinder, 10.23 inches diameter and 16.16 inches stroke. The piston, which is exposed to the atmosphere on its under side, drives the main crank by direct connection, and an air-compressing pump, about 3.5 inches diameter and 8.05 inches stroke, through a lever. Two poppet valves in the main cylinder head control the introduction of air from the atmosphere to the main cylinder and the exit of the contents of the main cylinder during exhaust. A smaller poppet valve introduces fuel, which is fed from an oil tank by a small pump. A fourth poppet valve controls the introduction of air from the air receiver for the purpose of starting the motor. The operation is as follows:

The receiver is charged with air at the desired maximum pressure (about 600 pounds per square inch). To start the engine the piston is placed at the top of its stroke. A hand-starting lever

is set so that all the cams upon the valve shaft are inoperative except the one connected to the starting valve, which then holds the latter open. The oil pump is operated a few strokes by hand, whereby the space around the stem of the starting valve is supplied with oil. On opening a cock by hand, the pressure from the receiver acts upon the piston and starts the latter downward.

At the end of the down-stroke the rotation of the cam shaft has automatically closed the starting valve, and put the three operating valves into regular action. The momentum acquired in the down-stroke carries the piston through an up-stroke, and compresses the contents of the main cylinder to about 520 pounds per square inch, whereby they are heated to a temperature of upwards of 1,000 degrees Fahrenheit. As the piston starts to make another down-stroke by momentum, the fuel valve opens, and the 600 pounds of air pressure in the receiver acting upon the fuel forces it into the heated contents of the cylinder, thereby causing combustion to occur, and power to be developed throughout the second down-stroke, the fuel valve closing at about one-tenth of the stroke of the piston, so that the heat developed is applied with a high degree of expansion. On the next up-stroke the exhaust valve is opened, permitting the cylinder to exhaust itself against the atmosphere. During the next down-stroke of the piston the inlet valve connecting with the atmosphere supplies the cylinder with pure air. This is compressed on the return stroke, and oil again introduced, and thence the operation of the engine proceeds regularly.

The pistons of the main and air cylinders are lubricated automatically from a reservoir.

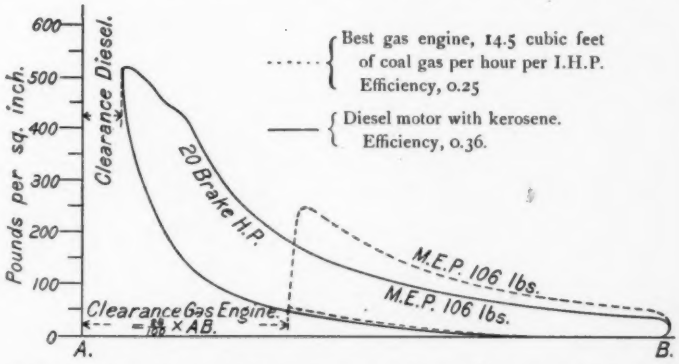
The revolutions of the engine are governed by a fly-ball governor, which controls the effective length of the stroke of the oil-feeding pump.

The engine was provided with a fly wheel, $6\frac{1}{2}$ feet diameter, weighing about 2,800 pounds. Its total weight, including fly wheel, was about 600 pounds per rated brake H.P., which is about 70 pounds greater than that of a Priestman oil engine, of 7 brake H.P., running 208 revolutions per minute.

The distinctive thermodynamic features of the engine compared with existing explosive gas and oil engines are:

1. That the cylinder contents during compression consist of air only, so that the compression may cause a pressure at the end of the in-stroke far above that which would cause premature explosion in a gas engine or explosive oil engine.

2. The greater degree of compression confines the contents of the cylinder when combustion occurs to about 0.07 of the cylinder volume, whereas in explosive gas or oil engines they occupy about 0.28 of that volume. (See cut.) Consequently



COMPARISON OF INDICATOR DIAGRAMS FROM A DIESEL MOTOR AND FROM THE BEST GAS ENGINE.

in the Diesel motor the available rate of expansion of the heated contents of the cylinder is several times as great as that of the gas and oil motors, and, therefore, the theoretical proportion of the heat of combustion utilized in work upon the piston is about twenty, twenty-five and thirty-six per cent., respectively, for the best explosive oil engine, gas engine, and Diesel motor.

3. The fuel in the Diesel motor burns gradually in the cylinder during the first one-tenth of the stroke (as does oil which is burned under a steam boiler), without augmenting the pressure above that due to the compression of the contents of the main cylinder by its piston. Consequently the particular proportion of air to fuel necessary to secure explosion is unnecessary.

The proportion of air to fuel may be anything, provided there is air in excess of that required for combustion. The proportions of this engine permit the excess to be about twenty-five per cent. at full load, and the presence of this excess of air ensures the steady maintenance of perfect combustion, which, together with the relatively small clearance space as compared to that of explosive engines, protects the engine against unreliable acting from fouling of the cylinder under continued action.

RESULTS OF EXPERIMENTS.

Tests were made with ordinary domestic kerosene, and with the various grades of petroleum used as fuel under steam boilers, which covered the operation of the engine for upward of 250 hours, to observe the behavior of the oil and the conditions of the interior of the engine after using each oil. During this time economy tests were made of from one to ten hours' duration, as per the data in accompanying tables. The principal commercial results abstracted from these tables are as follows:

1. With ordinary colorless domestic kerosene, of 120 degrees Fahrenheit flash, 150 degrees Fahrenheit fire test, and 0.784 gravity, at about 187 revolutions per minute, an average of 20.8 brake H.P. was developed, with an oil consumption of 0.534 pound, or 0.082 U. S. gallon per hour per B.H.P.; 13.05 B.H.P., with an oil consumption of 0.586 pound, or 0.0896 U. S. gallon per hour per B.H.P., and 8.78 B.H.P. with an oil consumption of 0.72 pound, or 0.110 U. S. gallon per hour per B.H.P. This shows an efficiency on B.H.P. of 25.8, 23.5 and 19.0 per cent. respectively. The corresponding indicated horse-power efficiencies were 37.7, 41.8 and 41.2 per cent. respectively. These results practically confirm the tests made on an engine rated at 19 B.H.P., at Augsburg, Germany, by Professor Schroeter and other experimenters, which for 17.33 English H.P. showed an oil consumption of 0.54 pound, or 0.0819 U. S. gallon of American kerosene per hour per B.H.P., and for 9.315 English H.P. an oil consumption of 0.63 pound, or 0.0956 U. S. gallon per hour per B.H.P., the efficiencies being as follows:

	Per cent. on—	
	17.33 H.P.	9.315 H.P.
Thermal efficiency on indicated H.P.	34.15	38.18
Thermal efficiency on brake H.P.	25.81	22.12

The same increase in indicated efficiency with reduction of load to one-half, shown by the German tests, is found in the New York tests. The mechanical efficiency, or the per cent. of the indicated power utilized at the brake of the New York motor was not as great as that of the motor tested in Germany—a result which is possibly attributable to the insufficiency of the foundation of the New York motor, which, by permitting excessive vibration, may have caused a waste of power between the cylinder and the brake. The New York motor showed the greater indicated efficiency, however, which is probably due partly to the slight difference of maximum pressure, and partly to the higher temperature of cooling water reducing the jacket waste.

The heat balance for the two cases is as follows:

HEAT BALANCE.

	BRAKE H.P.			
	21.51	8.78	17.33	9.315
	New York.		Augsburg.	
Heat, per cent.	37.2	41.2	34.7	38.9
Removed by jacket, per cent.	35.4	37.4	40.3	45.1
Remainder, per cent.	27.4	21.4	25.0	16.0
Total heat of combustion, per cent.	100.0	100.0	100.0	100.0

Examination of the interior of the engine during the use of the kerosene showed that there was no deposit on the surfaces, other than an infinitessimally thin film of lampblack on the cylinder and piston head, which did not increase with time. The bore of the cylinder was clean and polished.

2. With Pratt's fuel oil, which is a dark, straw-colored, clear petroleum, of 200 degrees Fahrenheit flash, 268 degrees Fahrenheit fire test, and 0.852 gravity, considerably used as a steam-boiler fuel, at practically the same revolutions, 20.07 B.H.P. were developed with an oil consumption of 0.613 pound, or 0.0862 U. S. gallon per hour per B.H.P.; and 12.56 B.H.P. with an oil consumption of 0.681 pound, or 0.0958 U. S. gallon, per hour per B.H.P. The operation with this oil was attended with the same insignificant lampblack deposit.

3. With a black, clear, Pennsylvania petroleum, known as

"Eagle" fuel oil, of 249 degrees Fahrenheit flash, 296 degrees Fahrenheit fire test, and 0.849 gravity, at practically the same speed, 20.75 B.H.P. were developed with an oil consumption of 0.56 pound, or 0.0784 U. S. gallon per hour per B.H.P. This oil left absolutely no deposit in the cylinder.

4. With Lima fuel oil, a black, clear petroleum of 0.856 gravity, at about the same speed, 20.73 B.H.P. were developed with an oil consumption of 0.59 pound, or 0.0826 U. S. gallon, per hour per B.H.P., and 10.77 B.H.P. with an oil consumption of 0.672 pound, or 0.0941 U. S. gallon, per hour per B.H.P. The operation with this oil was attended with no deposit in the cylinder whatever.

5. With California crude oil, a black, clear petroleum of 0.846 gravity, with practically the same revolutions, 20.07 B.H.P. were developed with an oil consumption of 0.626 pound, or 0.0887 U. S. gallon, per hour per B.H.P., and 11.44 B.H.P. with an oil consumption of 0.699 pound, or 0.099 U. S. gallon, per hour per B.H.P. This oil left absolutely no deposit in the cylinder.

With all these oils the engines started instantaneously and operated very steadily. The action of the valve gear is very smooth, and practically noiseless. The combustion occurred with perfect regularity, and was accompanied with no noise other than that due to the pulsation of the floor under the engine. There was also no noise from the exhaust of the engine audible a few feet distant from the chimney into which the exhaust pipe led.

The exhaust gases with all of the oils carried no soot, a piece of white paper being unsoiled by the impingement of the gases against its surface.

No deposit was found in a drum, forming part of the exhaust pipe, after the entire 250 hours of operation of the motor.

The cooling water is shown in the tables to be sixty pounds per B.H.P., with an outflow temperature of 127 degrees Fahrenheit. The engine operates safely, however, with water leaving the jacket at 140 degrees Fahrenheit, which would reduce the water to about fifty pounds, or six gallons per hour per B.H.P. The quantity of water used does not, however, constitute an expense

	California crude oil.			Eagle crude oil.			Lima crude oil.			
Kind of oil used										
Approximate brake horse power	20 H.P.	20 H.P.	11 H.P.	21 H.P.	11 H.P.	No load.	21 H.P.	15 H.P.	11 H.P.	No load.
Date of test	Aug. 12	Aug. 12	Aug. 12	Aug. 27	Aug. 27	Aug. 27	Aug. 27	Aug. 29	Aug. 27	Aug. 27
Duration, hours	0.99	0.99	1.00	0.76	1.00	0.49	0.96	10.01	1.01	0.50
Pressure in air tank, pounds per square inch	641.1	647.2	628.9	651.7	643.1	620.4	634.6	653.1	650.2	632.5
Temperature of exhaust gases, degrees Fahrenheit	...	...	...	740.+	516.	374.7	740.+	628.3	...	...
Inlet cooling water, degrees Fahrenheit	76.	76.	76.	74.	74.	74.	75.	75.6	75.7	75.
Outlet cooling water, degrees Fahrenheit	118.5	117.5	110.75	127.	123.9	116.5	115.7	126.2	125.	119.
M. E. P. of main cylinder, pounds per sq. in.	104.29	100.32	72.17	110.43	76.14	...	111.87	87.55	77.95	44.03
M. E. P. of air cylinder, pounds per sq. in.	70.62	74.48	78.93	76.135	79.445	75.58	83.31	79.78	83.86	82.75
Max. indicated press., main cylinder, lbs. pr. sq. in.	564.7	557.9	542.4	549.2	529.4	522.4	549.0	537.1	533.7	526.9
Revolutions, per minute	188.4	186.1	186.9	183.65	186.7	188.7	187.1	186.0	186.4	190.1
I.H.P. of main cylinder	32.09	31.32	22.63	34.02	23.85	13.23	35.11	27.32	24.37	14.04
Of air cylinder	2.90	3.10	3.09	3.13	3.32	3.19	3.49	3.33	3.50	3.52
Net	29.19	28.22	19.54	30.89	20.53	10.04	31.62	23.99	20.87	10.52
Brake H.P.	19.64	20.07	11.44	20.76	10.58	...	20.73	15.16	10.77	...
Friction H.P.	9.55	8.15	8.10	10.14	9.95	10.04	10.89	8.83	10.10	10.52
Mechanical efficiency, per cent	67.28	71.12	58.55	67.17	51.54	...	65.56	63.20	51.61	...
Oil consumption: Per hr., per B.H.P. { Pounds	0.688	0.626	0.699	0.555	0.691	...	0.590	0.579	0.672	...
Oil consumption: Per hr., per B.H.P. { U. S. gal.	0.0975	0.0887	0.0990	0.0784	0.0976	...	0.0826	0.0811	0.0941	...
Per hour per net I.H.P. { Pounds	0.463	0.445	0.409	0.373	0.356	0.520	0.387	0.366	0.347	0.487
Per hour per net I.H.P. { U. S. gal.	0.0656	0.0630	0.0579	0.0527	0.0503	0.0734	0.0542	0.0513	0.0486	0.0682
Efficiency on brake H.P., per cent	...	...	...	...	...	...	...	...	...	...
Efficiency on net I.H.P., per cent	...	...	...	...	...	...	...	...	...	...
Cooling water, per hour, per brake H.P., pounds	101.7	90.8	170.4	59.9	89.8	...	86.0	71.6	91.9	...
Heat units abstracted pr. hour, pr. B.H.P., B.T.U.	4,322	3,768	5,921	3,175	4,481	...	3,500	3,623	4,531	2,161
Quality of oil: Calorific value,† B.T.U., pr. pound.		19,376			19,742			19,648		
Probable calorific value, (Mahler's bomb)‡		...			...			...		
Flash test, degrees Fahrenheit		...			249			90		
Fire test, degrees Fahrenheit		...			296			160		
Specific gravity at 60 degrees Fahrenheit		0.846			0.849			0.856		

† Mahler's bomb.

‡ Corrected for condensed vapor, B. T. U., per pound.

	Ordinary Domestic Kerosene.						Fuel Oil.		
Kind of oil used									
Approximate brake horse power	19 H.P.	21 H.P.	21 H.P.	15 H.P.	13 H.P.	9 H.P.	20 H.P.	13 H.P.	No load.
Date of test	June 30	July 1	July 9	July 8	July 8	July 8	July 29	July 29	July 29
Duration, hours	2.00	4.25	1.966	2.00	0.49	1.50	1.94	2.07	0.81
Pressure in air tank, pounds per square inch	636.6	631.7	643.7	611.7	621.8	618.9	630.1	617.4	623.0
Temperature of exhaust gases, degrees Fahrenheit	740.+	740.+	740.+	673.	601.	511.5	...	...	...
Inlet cooling water, degrees Fahrenheit	73.0	74.0	76.0	77.0	78.0	78.00	74.0	74.6	74.5
Outlet cooling water, degrees Fahrenheit	109.2	110.6	119.9	108.6	128.0	120.6	113.5	104.	98.4
M. E. P. of main cylinder, lbs. per sq. in	99.565	103.909	108.462	87.612	81.197	66.763	104.65	78 67	39.70
M. E. P. of air cylinder, lbs. per sq. in	60.00	62.07	61.71	64.89	63.48	63.4	68.96	67.86	66.20
Maximum indicated pressure, main cylinder, lbs. per sq. in.	520.63	521.57	521.08	517.45	510.02	505.5	522.1	515.4	511.4
Revolutions, per minute	187.6	186.6	186.8	191.5	186.5	188.5	184.2	185.7	187.9
I.H.P. of main cylinder	31.33	32.53	33.99	28.14	25.40	21.11	32.34	24.49	12.51
Of air cylinder	2.01	2.07	2.06	2.22	2.145	2.17	2.27	2.25	2.22
Net	29.32	30.46	31.93	25.92	23.255	18.94	30.07	22.24	10.29
Brake H.P.	19.43	20.81	21.51	15.16	13.05	8.78	20.07	12.56	...
Friction H.P.	9.89	9.65	10.42	10.76	10.205	10.16	10.00	9.68	10.29
Mechanical efficiency, per cent	66.27	68.32	67.37	58.49	56.12	46.36	66.74	56.47	...
Oil consumption: Per hour, per B.H.P. — Pounds	0.546	0.534	0.549	0.594	0.586	0.721	0.613	0.681	...
Oil consumption: Per hour, per B.H.P. — U. S. gallon	0.0835	0.0817	0.0839	0.0908	0.0896	0.1102	0.0862	0.0958	...
Per hour per net I.H.P. — Pounds	0.36	0.365	0.370	0.347	0.329	0.334	0.409	0.384	0.427
Per hour per net I.H.P. — U. S. gallon	0.0553	0.0558	0.0566	0.0531	0.0503	0.0511	0.0575	0.0540	0.0601
Efficiency on brake H.P., per cent	25.20	25.77	25.06	23.17	23.48	19.09	...	...	...
Efficiency on net I.H.P., per cent	38.01	37.70	37.19	39.66	41.83	41.20	...	...	...
Cooling water, per hour, per brake H.P., pounds	...	...	82.4	126.8	...	117.8	99.1	154.3	...
Heat units abstracted per hour, per B.H.P., B.T.U.	...	...	3,617	4,007	...	5,018	3,914	4,629	...
Quality of oil: Calorific value,† B.T.U., per pound				20,156				19,980	
Probable calorific value, (Mahler's bomb)‡				18,604				...	
Flash test, degrees Fahrenheit				120				200	
Fire test, degrees Fahrenheit				150				268	
Specific gravity at 60 degrees Fahrenheit				0.784				0.852	

† Mahler's bomb.

‡ Corrected for condensed vapor, B. T. U., per pound.

item in the use of the motor, as it can be stored in an inexpensive reservoir, or cooling tower, which, once charged, will last indefinitely.

The cost of operation will then be practically confined to the cost of oil, and as the motor shows itself to be able to use oil obtainable at about two cents per gallon, the cost of a B.H.P. may be 0.2 cent per hour, which is slightly less than the cost of the same power from the average triple-expansion steam engine, with coal at $3 per gross ton.

OFFICIAL REPORT ON THE OPERATION OF ERICSSON'S SURFACE CONDENSER AND EVAPORATOR FOR MARINE ENGINES—1847.

[The following copy of a document in the possession of Mr. Charles H. Haswell is furnished us by that gentleman for publication, and is as interesting to the naval engineer of to-day as the apparatus was novel to those of 1847.]

"NEW YORK, *October 31st, 1847.*

"SIR: In acceptance of your invitation of the 17th ultimo, we, the undersigned, had the honor to meet together in the City of New York, with the view of testing and reporting upon an apparatus invented by Captain John Ericsson, for the purpose of supplying the boilers of marine steam engines with a continuous supply of fresh water, and applied by him under your direction in the U. S. Revenue Steamer *Legaré*.

"We have now respectfully to report that, on the 23d ultimo, we embarked in the *Legaré* at 12 M., proceeded to sea, and remained on board till the following morning. During this time the boiler was in operation fifteen hours, and we had ample opportunity of examining the means employed for supplying it with water and the results produced.

"By the ordinary method of condensing steam in marine navigation, boilers are supplied with the *water of condensation*, composed of the steam that is withdrawn from the boiler and the necessary quantity of salt water required for its condensation. Hence, a boiler in operation is constantly parting with steam (fresh water) and receiving salt water in exchange. The effect of this operation, uninfluenced by a correction, would be that in a few hours a degree of saturation of the water in the boiler would be reached that would precipitate upon the plates of the furnaces and flues a scale of sufficient thickness to arrest the passage of the heat to the surrounding water and cause the

destruction of the plates by exposing them to a temperature destructive of their tenacity. The correction in use is the removal of the water as it approaches saturation, and is effected by *blowing*, or *pumping off*.

"In the operation of either of these methods, it is apparent that there is a loss of the heat that has been imparted to the water blown or pumped off; that neglect to open or shut the blow-off cock, or in the admission of the required supply of water, involves the duration of the boiler, and may, as it frequently does, involve the lives of the passengers and crew and the safety of the vessel. Even when all practicable attention is given to blowing-off, salt scale will be deposited in long voyages, particularly in the middle latitudes, and accumulate to an extent that renders its removal imperatively necessary. This is at all times a difficult, and even under the most favorable circumstances an imperfect, operation, and when this deposit coats the surfaces of the flues the consumption of fuel is increased to an extent unsuited to the economy of mercantile enterprise, and to the duration of operation requisite for naval purposes.

"This evil may be avoided by furnishing the boilers with a full supply of fresh water, and as the weight could not be accommodated, nor the space spared in a vessel for an instrument and its fuel for the sole purpose of distilling the quantity required, it is obvious that the steam furnished by a boiler must be returned to it, after being condensed by the radiation of its heat to cold surfaces, and not by the admixture of water. This method was *proposed* by James Watt, so early as the year 1776, and has been effected to some extent by an instrument invented by Mr. Samuel Hall, of England, and applied to the engines of many steam vessels, in some of which, notwithstanding its imperfections, it is yet used. It has failed, however, to answer the full purposes desired and anticipated.

"In the arrangement of Mr. Hall, a great number of thin metal tubes, from one-half to three-fourths of an inch in diameter, were placed *vertically* in a condenser and exposed to a current of cold water from the sea, and into which the steam from the cylinder was admitted, for the abstraction of its heat

by the radiation of it to the water without the tubes. Now, it is evident that by this arrangement the condensed steam would run down the inner surface of the tubes, in its passage presenting a non-conducting lining to them, and in its collection at their bottom an obstacle to the current of the steam and a diminution of the effective radiating surface.

"With this method of condensation, it will be perceived that this instrument provides alone for returning to the boiler the water that has passed through the engine as steam. It follows, then, that all escapes of steam from the boiler or engine or water leaks from the boiler, pipes, etc., must be replaced by distillation, at an expense of fuel, directly as the evaporation. Further, continued use of this instrument exhibited an oleaginous deposit upon the inner surface of the tubes from the use of oil and tallow in the steam cylinder and on the valve faces, which, acting as a non-conductor, materially obstructed the condensation of the steam.

"The apparatus of Captain Ericsson was designed to obviate the difficulties and deficiencies developed in that of Mr. Hall, and is composed of two distinct instruments, a condenser and an evaporator; the first for the purpose of condensation, and the latter for a supply of fresh water to provide for any losses of steam or water from the boiler by escapes, leaks, gauge vents, &c., &c.

"The condenser is a cylindrical vessel, set at a slight inclination from a horizontal line, containing the requisite extent of radiating surface in metal tubes of *two inches* bore, with an open space at each end. By this arrangement there is free space for the current of steam to pass, and for the condensed steam to run down the lower side of the tubes, without presenting a lining of water to intercept radiation or an obstruction to the course of the steam. Connected with this is a pump, by which water from the sea is drawn in and forced through the spaces between the tubes and the inner surface of the shell of the condenser. Thus the latent heat of the steam is absorbed by contact with the tubes, and condensation is effected for the double purpose of affording a vacuum for the engine and of restoring fresh water

to the boiler, for continuous evaporation and condensation, to meet the requirements of the engine.

"The evaporator, as constructed, is a parallelopipedon, with a semi-cylindrical top and bottom, the lower portion of which is occupied by a number of tubes similar to those in the condenser, which communicate with a valve at each end of the steam cylinder, worked by the engine; around these tubes, and for some distance above them, water from the sea is admitted for the purpose of being evaporated, and the space above this water is open to the condenser, and consequently *in vacuo*. This instrument being designed to furnish fresh water to replace that which may be lost, its operation is resorted to only as occasion may require, and is effected in the following manner: When the piston is near the termination of its stroke, the valve referred to opens (above or below, as the case may be), and closes when the piston begins its return stroke; by this arrangement steam is withdrawn from the engine that has very nearly performed its full expansive effect, and passing into the tubes of the evaporator its heat is absorbed by the water surrounding them, and as this water is *in vacuo* it readily boils at a low temperature, and its vapor being led to the tubes in the condenser, it is condensed with the steam from the cylinder, and is supplied to the boiler.

"Upon the experimental trial to which you were pleased to request our attention, all practicable arrangements for correct observations were entered into; and with a view to acquire full and progressive notes of the operations of the apparatus, the observations of the various points were confided to special committees, which, upon the conclusion of the trial, reported full notes for furnishing the following, viz:

"The boiler was filled with fresh water from above the opening of the blow-off cock; below this, salt water had been left, from an impression of its effect being too inconsiderable to authorize its removal.

"At the commencement of the operation of the engine, the water in the boiler as indicated by a saline hydrometer, when at a temperature of 150 degrees Fahrenheit, was $\cdot\frac{6}{32}\frac{3}{2}$.*

* $\frac{1}{32}$ being the point of saturation of water when at a temperature of 200 degrees.

"The highest temperature of the *feed water* observed was 158 degrees Fahrenheit.

"The lowest 132 degrees, and the average 150 degrees.

"The highest *vacuum* observed was from sixteen to eighteen inches.

"The lowest from eleven to fifteen, and the average was from twelve to fifteen inches.

"The highest *steam pressure* was fifty-four pounds mercurial gauge.

"The lowest was twenty pounds, and the average was 48.6 pounds.

"The highest number of *revolutions* was forty-seven per minute.

"The lowest number was thirty, and the average 42.3.

"The point of cutting off was at three-eighths of the stroke.

"The temperature of the sea water was fifty-seven degrees.

"Duration of *operation* of the engine and boiler, fourteen hours and twenty minutes. Time during which steam was raised, twenty hours.

DIMENSIONS OF ENGINE, &c.

"*Cylinder.*—Thirty-six inches in diameter, with a stroke of piston of thirty-two inches.

"*Boiler.*—1,400 square feet of heating surface.

"*Condenser.*—637 square feet of radiating surface.

"*Evaporator.*—100 square feet of heating surface.

"Upon the arrest of the test, the freshness of the water was again tested, and when at a temperature of 150 degrees by a different thermometer than that used at the first operation (it having been broken in the interim) the hydrometer indicated $\cdot\frac{7}{32}\frac{5}{2}$; whether this difference in the indications is to be attributed to a change in the density of the water or to a difference in the thermometers, they being of different manufactures, we are unable to decide; fortunately the difference is quite inconsiderable, and is not regarded as deserving of further consideration.

"So soon as the temperature of the condenser was reduced to a degree that rendered an examination of it practicable, one of its heads was removed in our presence, and the tubes, when examined, were entirely free from any deposits or incrustation

upon their surfaces, and the opinion is entertained, that at a temperature of feed water commensurate with economy of fuel, any difficulty from the deposit of oleaginous matter in this instrument is not to be apprehended.

"Regarding the particular performances of the condenser and evaporator, it appeared that Captain Ericsson had relied too confidently on a general current of the cold water through the former instrument, whereas the current was quite partial, being but directly through its narrowest part, the sides of it; hence, the upper portion of it was almost inoperative, this feature was clearly developed by the application of a hand along the surface —while the effect of it was apparent in the moderate condensation indicated by an attached mercurial gauge.

"Of the evaporator, its capacity was clearly shown, in the facility with which the level of the water in the boiler could be raised through the space between two gauge cocks and by a resort to its operation, not being necessary for more than one-tenth of the time.

"Immediately after the close of this trial, measures were taken to effect a diffused operation of the cold water, and as diaphragms could not be introduced between the tubes to alter the current of the water, without incurring an impracticable delay, the expedient of causing the steam to circulate through the tubes was resorted to, and was effected by the application of diaphragms in the open space at each end of the tubes. Upon the completion of this, a further trial was had on Friday, the first instant, when several observations furnished the following:

Pressure of steam,	50	pounds mercurial gauge.
Revolutions,	47	per minute.
Vacuum,	20.5	inches.
Temperature of feed water,	150°	Fahrenheit.
Temperature of sea water,	62°	Fahrenheit.

Compared with the ordinary method of condensation, the value of the method observed is determined by an investigation and consideration of the following points, viz: Evaporation, pressures, consumption of fuel, safety and duration of the boiler.

1.—EVAPORATION. *Ordinary method.*

Temperature of feed water, 100° Fahrenheit.

Temperature of sensible and latent heats of steam	1,192°
Deduct temperature of feed water	100°
Heat to be added	1,092°

New method.

Temperature of feed water, 150° Fahrenheit.

Temperature of sensible and latent heats	1,192°
Deduct temperature of feed water	150°
Heat to be added	1,042°

Then $\frac{1042}{1092} = \frac{.954}{1.}$ which represents a gain in the evaporating temperature in the new method of 4.56 per cent.

2.—PRESSURES. *Ordinary method.*

Pressure of steam—mercurial gauge		50 lbs.
Vacuum, 28 inches	=	13.7 lbs.
		63.7 lbs.

Cut-off at three-eighths of the stroke.

Effective pressure on the piston	=	47 lbs.

New method.

Pressure of steam		50 lbs.
Vacuum, 20.5 inches	=	10 lbs.
		60 lbs.
Effective pressure on the piston		44.5 lbs.

Then $\frac{47}{44.5} = \frac{1.05}{1.}$ which represents a loss in pressure by the new method of 5 per cent.

3. CONSUMPTION OF FUEL. *Ordinary method.*

In the Gulf of Mexico and between the Tropics, it is necessary to blow off, when a hydrometer constructed similar to the one already referred to, indicates $\frac{2}{32}$; in the Northern and Southern Atlantic and Pacific Oceans, when it indicates $\frac{2.5}{32}$. Hence, $\frac{2. + 2.5}{2} = 2.25$ the average point for blowing off.

As the average degree of saturation of feed water is $\frac{.75}{32}$; the

quantity of water blown off compared to that fed to a boiler is as 75 to 2.25, which is in the proportion of 1 to 3.

Temperature of the water blown off at the pressure and degree of saturation given	290°
Deduct temperature of feed water	100°
Temperature lost by blowing off	190°
As the heat to be added for the purpose of evaporation is 1092°—	
$1092 \times 3 = 1$, the proportion of feed water evaporated =	2184°
And $190 \times 3 = 2$ the proportion of feed water blown off =	190°
The heat absorbed, is	2374°

Then $\frac{190}{2374} = \frac{.08}{1.00}$ which represents the loss of heat by blowing off in the ordinary method of 8. per cent.

SUMMARY OF RESULTS.

Gain by evaporation	4.56	per cent.
Do. do. consumption of fuel	8.	"
	12.56	"
Loss by pressure	5.	"
Total	7.56	"

Which is a saving in the expenditure of heat, affording a like economy in the consumption of fuel and altogether independent of the loss of heat, by the presence of scale in a boiler, when salt water is used, and from leaks incurred by the oxidizing effects of salt water.

With the *ordinary method*, the level of the water in a boiler is constantly varying from one or both of the following causes, viz: the quantity of the water blown off, or the particular extent of opening of the feed valve; while the effective operation of the feed pump and neglect of the blow-off valve, involves the burning, or an explosion of the boiler.

With the *new method*, these operations are set aside, thus blowing off is unnecessary and the supply to the boiler being first obtained from it, the transit being immediate and the communication incapable of restriction (for if the condensed water was not taken off by the feed pump, the condenser would choke and become inoperative), there can be no decrease in the level of the water, other than that arising from leaks of water and steam.

Further, the use of fresh water in a boiler will extend the term of its duration from three and five years to seven and nine.

With a further modification of the condenser, establishing a more diffused current of the cold water, it is evident that a full vacuum may be obtained, as the practicability of attaining this end by external condensation, has long since been developed, and with a less proportion of radiating surface than is exposed in the instrument referred to. From the analysis however here given regarding pressures and temperatures, it would appear that a full vacuum, with corresponding reduction of the temperature of the feed water is not authorized, and as such departure from the hitherto practice, furnishes the temperature necessary to prevent any oleaginous deposit upon the surface of the tubes of the condenser, practice and utility are in desired harmony.

A very effective and economical element in steam navigation arises with the operation of this new method, from the absence of scale in the boiler, the presence of which is unavoidable where salt water is used, and to avoid the formation of it as far as practicable, other than a low temperature and corresponding pressure are precluded by the waste of fuel and injury to the boiler consequent upon the existence of this scale, acting as a new conductor of the heat to the water—whereas, with the use of fresh water, higher pressures can be worked and economy of fuel attained in an increased expansion of the steam.

Reviewing the facts herein presented, we are of the opinion that the operation of the apparatus of Captain Ericsson, as far as developed, was eminently successful, and that, with the modification of the condenser suggested, a higher degree of vacuum can be readily obtained. In view of the very great importance of the successful introduction of this method of condensation in the merchant and naval services, we recommend to your consideration the propriety of sending the *Legarê* on a distant cruise, for the purpose of developing the advantages of the apparatus by continued and extended use.

Apprised of the ready attention you have given to this important subject, and the zealous interest you have manifested in its development, we cannot but congratulate ourselves and the pro-

fession with which we are connected, that you have seen fit to test this improvement by the construction of the apparatus on which we have been called to report. Such encouragement identifies in the merits of success the patron with the improvement, and is honorable to yourself no less than the nation in whose service you have bestowed it.

We have the honor to be, very respectfully,

Your obedient servants,

CHAS. H. HASWELL, *Engineer-in-Chief U. S. N.*
JAS. J. MAPES, *New York.*
LEWIS TAWS, *Philadelphia.*
JAMES MCFARLAN, *Union Ferry Co., N. Y.*
J. H. TOWNE, *Philadelphia.*
WM. SEWELL, JR., } *Chief Engineers U. S. N.*
WM. W. W. WOOD, }

To the Honorable
ROBERT J. WALKER,
Secretary of the Treasury,
Washington, D. C.

THE VALUATION OF COALS.*

By N. W. Lord.†

[Reprinted from "Engineering News," Feb. 16, 1899.]

The application of chemical analysis to the economic valuation of coals, so that it can furnish a guide to the consumer in the purchase of fuel, is hardly to be considered as in a satisfactory state of development. Many hundreds of "proximate" analyses of the various coals have been published by the State Geological surveys, as well as by others, and several attempts have been made to generalize these results, so as to arrive at workable formulas by which given samples of coal could be valued and their actual performance predicted, but the results, so far, do not seem to have met any general acceptance.

The subject is one to which the writer has had to give considerable attention, and it is the object of the present paper to present and discuss a number of unpublished tests and analytical results which have been collected from various sources.

The starting point in determining the value of any fuel for any purpose is, of course, its calorific power or "absolute heating power." This has been for so long a commonplace that it seems singular that only recently has the determination of this fundamental constant been required of chemists by the mechanical engineers. The calculation of the heating power from the ultimate analysis was so long considerd inaccurate to a degree precluding its use in valuing fuels that possibly on this account ultimate analyses of coals were rarely made in this country. The difficulties in the way of an accurate ultimate analysis are also

* A paper presented in Section C, Chemistry, of the American Association for the Advancement of Science, Boston meeting, Aug., 1898.

† Professor of Metallurgy in the Ohio State University, Columbus, O.

well known. At any rate it is a fact that many such results from reliable sources are not to be obtained for American coals.

In a paper by the writer, in connection with Mr. F. Haas, published in 1897 (Trans. Am. Inst. Mining Engineers, and Eng. News, March 25, 1897), there were a given number of ultimate analyses and calorimeter determinations which tended to show that the calorific value of the coal from a given bed was nearly constant over considerable areas of the seam, provided the observed value on any sample was reduced to an ash, sulphur and moisture-free basis.

Since the publication of the results referred to the Jackson coal, another prominent Ohio seam, has been investigated. This furnishes a large amount of first rate coal to the Ohio markets. The bed covers a considerable portion of Jackson county. Samples were obtained from mines opened in the eastern, western, northern, southern and central portions of the field. The samples were carefully taken by Mr. Laviers, engineer of the Superior Coal Company, and a former student of the writer's. The samples were from large amounts, and were intended to represent the average composition of the coal as mined at the selected points. The ultimate analyses and the calorimeter determinations were then made in the laboratory of the department of metallurgy by my assistant, Mr. Haas. The results are given in Table I.

The results shown appear fully to support the conclusions drawn in the former paper, that the heating value of the coal is practically constant throughout the bed. The failure of the last two samples to show close correspondence between the calculated values by Dulong's formula and the calorimeter results is contrary to our experience with other coals. These last two analyses are the average of duplicates which do not agree very satisfactorily, and, therefore, the results are a little open to question, as I fear some carbon may have escaped combustion. The other analyses given in the table are the average of very closely agreeing duplicates.

If the conclusion as to the comparative constancy of the heating value of the coal in any given seam is correct, then the

TABLE I.—ANALYSES OF JACKSON, OHIO, COAL.

Sample.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Sulphur.	Ash.	Moisture.	Volatile combustible.	Fixed carbon.	Calorimeter result.	Calorific power calculated from ultimate analysis.	Difference, per cent.	Calorific power calculated from *H*.	Difference, per cent.
1 Center	70.05	5.43	17.09	1.49	1.84	4.10	8.26	35.15	52.49	6,854	6,835	— .3	6,844	— .1
3 North	71.20	5.50	17.71	1.45	0.76	3.38	8.45	34.09	54.09	6,937	6,890	— .7	6,949	+ .2
4 South	70.12	5.49	16.96	1.50	1.45	4.48	7.02	37.66	50.82	6,956	6,860	—1.3	6,935	— .3
5 West	71.42	5.37	19.49	1.43	0.64	1.65	8.65	34.30	55.40	6,981	6,795	—2.7	7,077	+1.4
6 East	70.79	5.55	18.60	1.46	0.95	2.65	8.50	37.75	51.10	7,069	6,854	—3.1	6,992	—1.1
Average	70.72	5.47	17.97	1.47	1.13	3.25	8.17	35.79	52.78	6,953	...	...	...	...

$$H = \frac{6,934}{0.8745} = 7,929.$$

NOTE.—*H* equals the average of the calorimeter results minus 22.5 times the average per cent. of sulphur, the remainder multiplied by 100 and divided by 100 minus the sum of the average percentages of ash, sulphur and moisture. It stands for the average heating power of the combustible portion of the coal less the heat due to the combustion of the sulphur. The calculation of the heating power of any sample from a seam, when *H* is known, consists in multiplying *H* by 100 minus the ash, moisture and sulphur (in per cents.), dividing by 100 and adding 22.5 times the per cent. of sulphur.

determination of the heating power for any particular sample from the seam becomes a simple matter, if the ash, sulphur and moisture in the sample be known, and the seam constant for the kind of coal be known.

The substitution of complete sets of determinations of the ultimate composition and heating values of the coals in the different seams of a State for the present mass of proximate analyses of scattered samples would do much to clear the subject of coal valuations of its uncertainties.

The main point at issue, however, is the relation between the calorific power of the fuel and its industrial value and how far this can be determined by chemical methods. With a view to getting more light on the subject, the writer has collected a considerable number of results of actual boiler tests made on the coals of the seams which have been examined in the laboratory of the department. These results have been furnished the writer by various persons in private communications. For commercial reasons the names of these furnishing the results cannot usually be given, but all the results are from large consumers of coal, thoroughly competent to judge of the care with which these tests were made. A number of the results are from tests made by Professor Hitchcock, of the Department of Mechanical Engineering of the Ohio State University, who has kindly furnished me with the evaporation figures he obtained. In the tests made by Professor Hitchcock most of the chemical and calorimeter work was done by Mr. Haas, my assistant, in the department of metallurgy, to whose industry, accuracy and enthusiasm I am indebted for many of the results herewith presented.

The accompanying table gives the evaporation tests, together with the refuse or ashes, determined practically from the weights of the material collected in the ash pits, as reported by those furnishing the tests. The percentage of unburned coal as given in the table is estimated in most cases by proportion from the percentage of ash found in the ash-pit refuse and percentage of ash in the analysis of the coal. In other cases it is calculated by deducting from the per cent. of ash-pit refuse the per cent. of ash found in the analysis of the coal.

All the analyses were made in the laboratories of the department, and of samples taken from the coal used in the boiler tests.

The evaporation results given in Table II were obtained from different types of boilers and grates and by different observers,

TABLE II.—BOILER TESTS WITH VARIOUS COALS.

No.	Water evaporated from and at 212° F.	Refuse.	Ash by analysis.	Coal unburned.	Moisture.	Calorific power.	Kind of boiler.
	Pr. pound.	*Pr. ct.*	*Pr. ct.*	*Pr. ct.*	*Pr. ct.*	*h. u.*	
Pocahontas Coal.							
1	9.94	11.8	7.92	3.9	0.77	7,988	Water tube, *s.*
2	9.29	5.94	6.99	3.0	0.61	8,080	Water tube, *h.*
3	8.37	8.26	5.63	2.5	0.63	8,185	Water tube, *h.*
4	8.04	8.88	5.81	4.6	...	...	Multitubular.
5	7.73	14.61	5.81	5.7	...	...	Multitubular.
6	10.66	...	3.83	0.2	...	8,409	Water tube, *s.*
7	10.89	...	6.05	0.3	...	...	Water tube, *s.*
Average	9.28	...	6.01	2.9	...	8,140	
Hocking Coal.							
8	7.72	13.83	10.59	6.7	6.50	6,499	Water tube, *s.*
9	6.23	6.97	9.10	3.2	6.45	6,603	Water tube, *h.*
10	6.06	6.38	...	...	6.72	6,882	Water tube, *h.*
11	6.52	6.38	8.50	2.3	6.40	6,610	Water tube, *h.*
12	7.34	9.76	7.48	3.3	...	...	Multitubular.
13	7.15	11.32	7.48	3.3	...	...	Multitubular.
14	7.72	4.36	4.32	2.7	...	...	Multitubular.
15	8.72	...	9.37	0.7	6.68	6,616	Water tube, *h.*
16	8.00	...	12.85	0.9	6.00	6,482	Water tube, *h.*
17	7.45	...	16.95	8.5	7.55	6,089	Water tube, *s.*
18	6.52	...	12.95	5.0	6.20	6,454	Water tube, *s.*
19	6.22	...	12.45	4.1	6.10	6,569	Water tube, *s.*
20	6.78	...	14.85	8.5	6.13	6,458	Water tube, *s.*
Average	7.11	...	10.55	4.1	...	6,526	
Thacker Coal.							
21	9.37	12.77	7.25	7.10	1.27	7,789	Water tube, *s.*
22	8.79	12.15	...	...	...	...	Water tube, *s.*
23	7.55	5.68	6.50	2.3	1.40	7,768	Water tube, *h.*
24	7.39	6.44	7.50	2.5	1.60	7,738	Water tube, *h.*
25	8.59	...	7.87	7.8	1.56	7,587	Water tube, *s.*
Average	8.36	...	7.28	4.9	...	7,720	

s = mechanical stoker; *h* = hand-fired.

Upper Freeport Coal.

No.	Water evaporated from and at 212° F.	Refuse.	Ash by analysis.	Coal unburned.	Calorimeter value.	Kind of boiler.
	Pr. pound.	*Pr. ct.*		*Pr. ct.*		
26	7.27	17.34	11.89	5.4	...	Stationary.
27	7.41	16.48	9 58	6.9	...	Stationary.
28	7.62	14.30	7.82	6.5	...	Stationary.
29	7.65	11.54	9.17	2.3	...	Stationary.
30	7.84	12.70	7.66	5.0	...	Stationary.
31	7.42	14.08	9.42	4.7	...	Stationary.
Average	7.53	...	9.26	5.1	7,326	
32	6.45	...	9.10	...	7,326	Locomotive.
33	7.11	...	8.10	...	...	Locomotive.
34	6.54	...	10.45	...	...	Locomotive.
35	6.72	...	8.70	...	...	Locomotive.
36	6.23	...	8.25	...	...	Locomotive.
Average	6.61	...	8.92	...	7,212	

Darlington Coal, Pennsylvania.

37	7.26	14.39	4.35	10.0	...	Stationary.
38	7.34	14.16	8.75	5.4	...	Stationary.
39	7.62	12.22	4.95	7.3	...	Stationary.
40	7.51	14.98	6.65	8.3	...	Stationary.
Average	7.43	...	6.18	7.7	7,652	
41	7.15	...	8.70	...	...	Locomotive.
42	6.47	...	8.80	...	...	Locomotive.
43	6.04	...	8.05	...	...	Locomotive.
Average	6.55	...	8.52	...	7,283	

Pittsburg Coal.

44	8.00	11.52	5.93	5.6	...	Stationary.
45	8.43	11.82	7.95	3.9	...	Stationary.
46	7.89	11.60	6.08	5.5	...	Stationary.
47	7.83	12.55	9.25	3.3	...	Stationary.
48	7.88	11.57	8.86	2.7	...	Stationary.
Average	8.01	...	8.01	4.2	7,596	
49	8.12	...	9.05	...	...	Locomotive.
50	7.66	...	9.05	...	...	Locomotive.
Average	7.89	...	9.05	...	7,374	

and hence can not be taken as giving the comparative values of the different samples of coal tested, but in the aggregate they represent a varied experience in the use of coals of the same character for the purpose of steam raising.

The evaporation figure given by a single test in any given boiler and furnace is, of course, dependent upon a number of factors, only one of which is the absolute heating power of the coal. This will account for the wide variation shown in the results obtained from coals of nearly the same heating power and of the same seam. Thus Hocking coal gives evaporation varying from 6.22 up to 8.72, the corresponding calorific values being 6,616 and 6,569, a difference of evaporation of nearly 30 per cent., and a difference in calorific power of less than 1 per cent. These two tests were made in Columbus, and I am able to present the complete "heat balance" as computed for the test by Mr. Haas from his observations of the flue temperature, composition of the flue gas, analysis of refuse, etc. The tests which gave 8.72 pounds evaporated was made on "run of mine" coal in a hand-fired furnace. The flue gas was analyzed every thirty minutes, and the flue temperature read at the same time. The coal and refuse were carefully sampled and analyzed. The average flue temperature over that of the outside air was 244 degrees centigrade, the average excess of air in the flue gas 71 per cent. of that required for complete combustion. The heat distribution was as follows:

	Calories.	Per cent.
In products of combustion	563	8.5
In excess of air in flue gas	348	5.3
In latent heat in flue gas	276	4.2
In unburned coal	47	0.7
In evaporation	4,683	70.8
In radiation, etc. (by difference)	699	10.5
Calorimeter test (by bomb)	6,616	100.

The test which gave 6.22 pounds evaporation was made on "pea and slack" coal fired by a mechanical stoker. The flue temperature in excess of the external air was 274 degrees centigrade, and the average air excess in the flue gas was 281 per

cent. The gas analyses were made every fifteen minutes by the Orsat apparatus. The heat distribution was as follows:

	Calories.	Per cent.
In products of combustion	633	9.6
In excess of air in flue gas	1,542	23.5
In latent heat in flue gas	2,259	3.9
In unburned coal	204	3.1
In evaporation	3,340	50.8
In radiation, etc. (by difference)	591	9.1
Calorimeter test (by bomb)	6,560	100.

Another sample of coal in the same boiler as the last test gave 6.52 pounds evaporated. Test made on pea and slack Hocking coal. Average flue temperature over external air, 265 degrees centigrade; average air excess, 205 per cent:

	Calories.	Per cent.
In products of combustion	604	9.3
In excess of air in flue gas	1,069	16.5
In latent heat in flue gas	265	4.1
In unburned coal	308	4.8
In evaporation	3,501	54.2
In radiation, etc. (by difference)	707	10.9
Calorimeter test (by bomb)	6,454	100.

Samples like the above could be given of numerous other tests. The facts illustrated are, however, well known to all who have worked in connection with boiler tests. To the boiler maker or user the chemical analysis of the coal and its calorific value are of vital importance, as they enable him to construct just such a heat balance as above quoted, and to judge from this the performance of the boiler. The recent report of the committee on boiler tests to the Society of Mechanical Engineers dwells fully on the importance of this work.

Only the ultimate analysis of the coal will serve the purpose. Fortunately the ultimate analysis calculated from the average analysis of the seam can be used with little error if applied to the special coal samples with due correction for moisture, ash and sulphur in the sample tested. Boiler tests are expensive and demand mechanical engineers as well as chemists. The simple

evaporation test without the heat balance gives no proper valuation of the single coal sample itself, as the figures quoted clearly show. How far can chemical analysis alone be used in predicting the boiler test, as it were? This resolves itself into an examination of how far the well-known formulas and methods for computing heating effects and losses can be depended upon. The consideration of any heat balance such as those quoted shows that besides the useful or available portion of the heat, there are two classes of heat losses. First, those dependent on the coal, and second, those dependent upon the grate, the style and condition of the boiler and the skill of the fireman. The second of these is not a matter determinable by the chemist from the analysis of the coal. By the general principle of averages, losses of this kind should tend to equalize themselves when a considerable number of results on the same coal are united, thus by taking the average of a series of evaporation tests a result should be obtained which would give a difference between the heat used in evaporation and the total heat devoloped that could be divided into two parts, one varying with the kind of coal, and the other more or less constant and independent of the kind of coal. This latter loss could be included in the valuation of the coal in one of two ways, either by subtracting a value for it as found from the average coal burned or by subtracting the value for it found in what might be considered the best tests. It would seem that the latter plan would be the more desirable, as it would tend to value the coal at an attainable figure, and yet one which would serve as a guide to the user and furnish a check on the performance of his grate and boiler. If a standard set of conditions in this regard be assumed it is obvious that all coals would be graded by them fairly.

The losses dependent upon the composition and character of the coal can be easily computed by well-known formulas. They comprise the heat latent in the products of combustion in water vapor, and the sensible heat in the product of combustion. The heat in the air excess, if the latter is measured in percentages of the air required to burn the coal, is to a certain extent dependent upon the composition of the coal for its computation and

expression. One loss, varying with the coal as well as the grates, will be the percentage of unburned coal, which more or less depends on the friability, coking power and mechanical condition of the coal. The relation of this to the mode of combustion is, however, much closer than it is to the character of the coal, as is easily seen by reference to the results quoted in the table. The results for Pittsburg coal and for the Hocking coal are in the averages about the same, while the variation in each coal, according to the grate used, is very large. One of these is, as is well known, a strongly coking coal, and the other a typically non-coking coal. This factor in the valuation of the coal is best estimated from an analysis of the refuse from grates burning the coal. A simple estimation of the ash or non-combustible portion of the refuse is all that is needed. This assumes that the unburned portion is coal and not coke, which is probably only partially true. The error caused by assuming it to be pure carbon would in any case be but trifling. Numerous analyses have been made in our laboratory, which show that the unburned coal in the refuse is to a considerable extent uncoked. For example:

REFUSE FROM ASH PIT.

	Thacker coal.	Pocahontas.	Hocking.
Moisture	0.15	0.40	0.83
Volatile	3.37	4.50	7.25
Fixed carbon	29.96	32.50	33.27
Ash	64.00	62.60	58.65

The figures for the Thacker coal are the average of two analyses. It will be seen that the volatile matter is considerable, though not equal to what it would be in the coals. The radiation and other losses determined by difference in the boiler tests are somewhat variable. The writer has been in the habit of assuming this amount at 10 per cent. of the calorific power of the coal. This assumption is, of course, arbitrary, but a number of boiler tests made at the University give results approximating quite closely to this figure. If this correction be applied to the common formulas used in heat calculations, we would have for the relative practical heating value of the coal, or what might be called the "available heating power," the following:

"Available heating power" $= \frac{9}{10}$ calorific power—latent heat—T (into water equivalent of products of combustion added to water equivalent of excess of air).

The evaporating power would be equal to the available heating power multiplied by 1 minus the fraction of unburned coal, and divided by 537. The air excess is easily determined from the flue gas analysis. If this analysis is expressed in parts by weight, then the ratio of the air excess, that is, the air present in the gas, divided by the air used in the combustion of the fuel almost exactly equals $\frac{O}{\frac{3}{10}N-O}$. Let A stand for the ratio of the air excess and insert the values of the specific heats, and let C H S and O stand for carbon, hydrogen, sulphur and oxygen, shown in the ultimate analysis of the coal, and we have the following formula.

Available Heat $=$ 0.9 calorific power $-$ 9 H $\times$ 589. $-$ T° carbon (11/3 $\times$ 0.217 $+$ 8/3 $\times$ 3.33 $\times$ 0.244 $+$ 8/3 A $\times$ 4.33 $\times$ 0.237) $-$ T° H $\times$ 9 $\times$ 0.48 $-$ T° (H $-$ 1/8 O) (8 $\times$ 3.33 $\times$ 0.244 $+$ 8 $\times$ 4.33 $\times$ 0.237 A) $-$ T° sulph. $\times$ (2 $\times$ 0.154 $+$ 3.33 $\times$ 0.244 $+$ 4.33 $\times$ 0.237 A). This reduces to

Available Heat $=$ 0.9 calorific power $-$ 5,301 H $-$ T° C (2.963 $+$ 2.738 A) $-$ T° H $\times$ 4.32 $-$ T° (H $-$ 1/8 O) (6.498 $+$ 8.209 A) $-$ T° S (1.121 $+$ 1.027 A).

Of course this is only text-book work, but where the values of A and T are determined by experiment and the value of the coal unburned by analysis of the refuse, the above expression will give the evaporation shown by the coal within a reasonably close figure, as the writer has verified repeatedly. When the C O forms a noticeable percentage of the gas the results will be unreliable. This condition is on the whole uncommon, and is usually associated with a small air excess, and is obviously wasteful of coal. In the records of many flue gas analyses in the department of metallurgy, few show more than fractions of a per cent. of C O present. The grading of coals generally by any such formula will, however, depend upon the assumption of standard values for A and T. In order to apply it to the boiler tests given in the table, I have assumed, for purpose of comparison, A equal to 1 (or 100 per cent.

of air in excess of that required to burn the coal), and T equal to 200° C., as representing a fairly attainable figure in good practice. If these conditions be introduced into the above formula it takes the following form, provided the sulphur is omitted as unimportant, in such a formula only intended for practical results:

$$\text{Evaporating power} = \frac{1}{537} - (9/10 \text{ cal. P} - 9{,}106\ \text{H} - 1{,}140\ \text{C} + 377\ \text{Ox}).$$

Applying this to the average results on the coals tested, the average composition of the Pocahontas coal, as shown by analyses previously published, is as follows: C, 84.87; H, 4.29; O, 3.51; N, 0.85; S, 0.59; Ash, 5.89.

By the assumed formula this would give an evaporating power of 11.2, assuming the coal all burned. The average unburned coal of the test is 2.9 per cent. Correcting for this, there remains an evaporative efficiency under the assumed conditions of 10.9 pounds. The average of the tests is 9.28. The best test is 10.89.

The average composition of the Hocking coal as given in the paper previously quoted is: C, 68.03; H, 5.29; O, 15.64; N, 1.44; S, 1.59; Ash, 8.00. The formula gives for its evaporative value under standard conditions, 8.9 pounds, or allowing for the average unburned coal, 8.6 pounds. The best result of the test is 8.72. The average is 7.11. In the same way the Thacker coal, having the ultimate composition: C, 78.65; H, 5.17; O, 7.22; N, 1.17; S, 1.28; Ash, 6.27; gives for its evaporative efficiency 10.5. Correcting for the average ash leaves 10 pounds. The maximum value in the test is 9.37. The average is 8.36. The number of tests on this coal is noticeably less than on the others. The average composition of the upper Freeport coal is: C, 72.65; H, 5.06; O, 8.95; N, 1.34; S, 2.89; Ash, 9.10. This corresponds to a standard of evaporation of 9.9 pounds, or, correcting for average unburned coal on the six tests made in stationary boilers, 9.4 pounds. The average evaporation is 7.53 in the stationary boilers. The locomotive tests are much below the others, averaging 6.61 pounds.

The Darlington coal, with the average composition of C, 75.19;

H, 5.14; O, 9.05; N, 1.46; S, 1.98; Ash, 7.18; computed in the same way, gives 10.2 pounds evaporated, which, corrected for the average unburned coal, becomes 9.4 nearly. The average evaporation in stationary boilers is 7.43; in locomotive boilers, 6.55 pounds.

The Pittsburg coal has for average composition: C, 75.24; H, 5.18; O, 8.24; N, 1.51; S, 1.79; Ash, 8.00. This gives for evaporation, under assumed standard conditions, 10.2, or, correcting for average unburned coal, 9.8 pounds. The average evaporation in stationary boilers is 8.01, and in locomotives 7.89. In the locomotive tests quoted no figures were furnished me for the amount of refuse. Losses through grates and stack in the locomotives must be a large factor in the case of the more friable coals. If we unite together these computed standard evaporations of the different coals with the actual as shown in the averages of the boiler tests, we have the following table:

Coal.	Calculated evaporation.	Average actual.	Difference.
Pocahontas	10.9	9.28	1 68
Hocking	8.6	7.11	1.49
Thacker	10.0	8 36	1.64
Upper Freeport	9.4	7.53	1.87
Darlington	9.4	7.43	1.97
Pittsburg	9.8	8.01	1.79

The average difference between the calculated values and the actual evaporations is 1.73 pounds, showing that the average duty of the coals is about $1\frac{3}{4}$ pounds less than would be given under the standard conditions.

The relative values of the coals, as rated by the results of the boiler tests by the calculated values, and by the average calorimeter results, is shown in the following table; the Hocking coal is assumed as having a value of 100, and the others compared with it by dividing each result by the corresponding result for Hocking coal:

Relative values of coal. (Hocking coal = 100.)

Coal.	By calorimeter.	Boiler test.	Calculated evaporation.
Hocking	100	100	100
Pocahontas	122	127	131
Thacker	116	117	116
Freeport	109	106	109
Darlington	112	105	109
Pittsburg	113	113	114

This table shows that a coal like Pocahontas, high in carbon and low in hydrogen, gives higher evaporation duty in proportion to its calorimeter value than those coals higher in hydrogen and oxygen, as was, of course, to be expected. The foregoing results are not sufficiently numerous to serve as more than indications, but as far as they go they show that the valuation of coal by the calorimeter and ultimate analysis gives results of importance which would serve as a useful guide in selecting fuels for steam raising. Furthermore, they show that calculations based on the averages for the seam, when such analyses are obtained by the analysis of carefully prepared samples, can be depended upon in rating the relative values of coals to the consumer.

I have not attempted here to apply these calculations to the individual results. Close correspondence in the special cases is not to be expected for reasons previously shown, but the conclusions drawn from the average results are offered as testifying to the reliability of well-known methods of heat calculations and as an argument for the more general introduction of ultimate analysis on the valuation of coals. It would appear especially desirable that public surveys of coal fields should adopt this method of analysis. The results further suggest that coal users should realize more fully that coals can be valued by analysis, and that it is important that their boilers and grates be held responsible for failure to approximate the chemical valuation.

SHRINK AND FORCE FITS.

By Professor Jno. J. Wilmore.

[Reprinted from "American Machinist," Feb. 16, 1899.]

Last spring two of my senior class students in Mechanical Engineering, Messrs. Jno. Haralson and J. L. Wood, selected the above as a subject for thesis work. The extremely meager list of references for reading that I was able to give them led me to think that perhaps this subject had not received much attention, and an abstract of the results obtained might be of some general interest.

The experiments consisted in shrinking and forcing steel spindles into cast-iron disks, and afterward pulling some of them out, and twisting the others in the holes. A number of sound gray iron disks, about 6 inches in diameter by 1 inch thick, with a boss on one side about 2 inches in diameter by $\frac{1}{4}$ inch projection, were secured. It was specified that these disks should all be molded by one man and poured from the same ladle of iron, in order that they should be as nearly uniform in texture as possible.

A $\frac{7}{8}$-inch hole was drilled in the center of each of these disks and they were then chucked in a lathe and bored out to $\frac{63}{64}$ inch and faced. They were then reamed, first with an ordinary 1-inch fluted reamer about two thousandths of an inch under size, and finished with an adjustable reamer to one inch with an error believed not to exceed 0.00025 of an inch.

The spindles were made from a good quality of machinery steel $1\frac{1}{4}$ inches in diameter. The end for a distance of $1\frac{1}{4}$ inches was turned down to a diameter of $1\frac{1}{32}$ inches, and a shallow groove $\frac{1}{8}$ inch wide was cut next to the shoulder to allow the emery wheel in the grinding operation to clear at the end of its travel. They were then put on universal grinding machine and

carefully brought to diameters varying by five ten-thousandths of an inch, as follows:

Number of spindles.	Finished diameter.
4	1.001 inches.
5	1.0015 "
4	1.002 "
5	1.0025 "
1	1.003 "

The end for $\frac{1}{8}$ of an inch was slightly tapered to enable the spindle to readily enter the hole; the actual surface in contact being thus reduced to 1 inch in length.

About half these spindles were then forced into the holes in the disks by means of a testing machine, care being taken to insure a straight and true entrance, the maximum pressure required in each case being noted. The remainder of the spindles had the disks shrunk on; the latter being heated only enough to admit the spindle. Some of each sort were then tested by pulling the spindle out of the hole, and the others by twisting the disk on the spindle.

The arrangement of the parts for the tension tests, may be described as follows: A disk similar to those previously described, except it had a larger and longer boss, was threaded with a $1\frac{1}{2}$-inch standard thread, to which was fitted a spindle. This, as well as all of the test disks, had four bolt holes drilled through the flange. The test pieces were then bolted one by one to this threaded disk, put in the testing machine, the spindle pulled out and the maximum pull noted.

In testing the force necessary to turn the disk on the spindle, the latter was placed on a lathe between centers. A cast-iron arm was bolted to the disk and supported in a horizontal position by a knife edge having a bearing ten inches from the center of the disk. The support for the knife edge was a piece of scantling resting on a platform scales. A heavy pipe wrench on the spindle with a "foot-ball man" at the handle furnished the necessary turning force. In the tables, the figures show the forces reduced to the circumference of the spindle in order to make them comparable with the tension specimens.

The following tables show the numerical results. It should be remembered that all the holes were 1 inch in diameter and $1\frac{1}{4}$ inches long, the variation in diameter being made in the spindle.

It will be noted that the shrink fits are quite uniformly about three times as strong as the force fits of corresponding size, both in tension and torsion. The force fits were made without lubrication other than the small amount of machine oil adhering to the spindle on account of having been wiped with oily waste after grinding to prevent rusting. The spindles and holes were found to be smooth and in good condition after the tests. The maximum force was required to start the spindle. After movement had once occurred between the two surfaces, a much smaller force was required to start it a second time. No. 19 test piece was tried in torsion up to the limit of the scales without movement.

The figures from the table, with the exception of No. 8, were plotted on co-ordinate paper, and show some interesting charac-

Number of specimen.	Diameter of spindle.	Kind of joint.	Force necessary to start joint.	Force per square inch.	Kind of test.
	Inches.		*Pounds.*	*Pounds.*	
1	1.001	Force.	1,000	318	Tension.
2	1.001	Shrink.	5,320	1,695	Tension.
3	1.001	Shrink.	5,820	1,853	Tension.
4	1.001	Shrink.	2,200	700	Torsion.
5	1.0015	Force.	2,150	685	Tension.
6	1.0015	Force.	2,200	700	Torsion.
7	1.0015	Force.	2,800	892	Torsion.
8	1.0015	Shrink.	7,200	2,290	Torsion.
9	1.0015	Shrink.	9,800	3,118	Torsion.
10	1.002	Force.	2,570	818	Tension.
11	1.002	Shrink.	7,500	2,385	Tension.
12	1.002	Shrink.	8,100	2,580	Tension.
13	1.002	Force.	4,200	1,335	Torsion.
14	1.0025	Force.	4,000	1,272	Tension.
15	1.0025	Shrink.	9,340	2,974	Tension.
16	1.0025	Shrink.	9,710	3,090	Tension.
17	1.0025	Force.	4,600	1,465	Torsion.
18	1.0025	Shrink.	13,800	4,395	Torsion.
19	1.003	Shrink.	17,000	5,410	Torsion.

teristics. (No. 8 was omitted because it was known to be too low, the beam of the testing machine being at rest at the top of its travel at the time the joint failed.) These points naturally resolve themselves under four heads: First, force fits under tension; second, force fits under torsion; third, shrink fits under tension; fourth, shrink fits under torsion. By reference to the curves, it was observed that the general direction or slope of the curve was about the same for the first three, but for the fourth the angle made by the curve with the vertical axis was about 30 per cent. greater. This would seem to indicate that the strength increases more rapidly with the diameter under these conditions. The question naturally arises as to how far these conditions would hold, and an interesting field for further investigation is opened up. The maximum tangential effort of 17,000 pounds, obtained in the tests, would, with a coefficient of friction of .2, give a normal pressure of 85,000 pounds, or 27,070 pounds per square inch, a pressure well within the crushing strength of the metals employed. With greater difference between the diameter of spindle and hole, it might be necessary to force the spindle into a heated disk.

It seems evident from these experiments that the shrink fit is the better of the two, but in practical work it is not always the best way but the "good enough way" that is sought. If, therefore, the force fits are good enough and can be made more cheaply than shrink fits, they will be used in every case.

Let us assume that the pressure per square inch of bearing surface between the disk and the spindle would remain constant for larger sizes, the allowance per inch in diameter remaining the same. Let this allowance be two thousandths of an inch per inch in diameter, a fair average value as used in practice. Take an engine shaft five inches in diameter, upon which a crank disk is to be forced. The length of the hole in the disk should at least equal the diameter, say five inches. Then the area of the surface in contact would be $3.1416 \times 5 \times 5 = 78.54$ square inches. Referring to the table, we see that specimen No. 13 is 1.002 inches in diameter, and in other respects complies with the conditions assumed above. It required 4,200 pounds to start

the joint. Then $4{,}200 \div (3.14 \times 1) = 1{,}337.5$ pounds per square inch of surface in contact. Now $1{,}337.5 \times 78.54 = 105{,}047.25$ pounds, the force acting at the surface of the shaft required to start the joint.

Now a 5-inch shaft would not be likely to be found on an engine with a cylinder larger than 12 inches in diameter by 18 inches stroke. Then 105,047.25 multiplied by 2.5, the radius of the shaft, and divided by 9, the radius of the crank, gives 29,179.8 pounds acting on the crank pin at its point of maximum turning effort, required to move the joint. With a pressure of 100 pounds per square inch on the piston, this would require a piston of 291.8 square inches area, whereas a 12-inch piston has only 113 square inches, thus giving a factor of safety of 2.6 nearly. This would probably be too small to satisfy the engine builder for cranks, pistons and the like, but there are many other places in mechanical construction for which the factor would be ample. If, however, the crank should be shrunk on, the joint, according to our table, would be from twice to three times as strong, and the factor of safety would rise to a point that should satisfy the most exacting. A comparison of the cost of making a shrink fit with that of making a force fit with the keying necessary for safety, would determine in any particular case which one to use.

In conclusion, the author acknowledges the incompleteness of the tests, but hopes that the results obtained justify their publication. The men who carried on the work were young and inexperienced in the production of work having a high degree of accuracy, and as a consequence, many of the specimens prepared were rejected before being used in the tests.

DIRECT UTILIZATION OF PRODUCER GAS IN EUROPE.

In connection with the notes in the last number of the JOURNAL on the subject of power from blast furnace gas, the following summary by E. P. Buffet, of an article contributed to "La Geniè Civil" of Paris by M. Aug. Dutreux, will be found of much interest. The summary is reprinted from the "American Machinist," and gives a review of the results, so far as known, that have been obtained in Europe with the use of producer gas in gas engines. The data are part obtained from previous publications and part of the author's own collection. His conclusions are to the effect that all the objections commonly raised against this employment of producer gas can be, and have been, overcome.

Those objections are chiefly as follows:

1. Very feeble calorific power of the gas, and its variable composition.
2. Dust getting into the cylinders and wearing their mechanism.
3. Difficulties of ignition arising from the great quantity of inert gas.
4. Variations of the pressure of the gas.
5. Too great dimensions of the engine cylinders required, because of the feeble calorific power of the gas.
6. Difficulty of starting motors of high power.

In answering the first point, recourse is had to a theoretical study of producer gas by M. Hubert, Engineer of the Corps of Mines of Belgium, founded upon data obtained by Mr. Hiertz, the blast furnace manager of the John Cockerill works at Seraing, Belgium. Assuming the characteristic ratio of the operation of the furnace, that is the proportion of carbonic acid to carbonic oxide, to be .5 or .7, the calculations give, respectively, 1,166 and 1,046 calories per cubic meter of the gas when reduced to a

standard of 0° centigrade and 760 millimeters of pressure. Actual tests of producer gas made with the calorimetric shell by Mr. Witz gave a maximum of 1,084, a minimum of 961, and a mean of 997 calories with twelve samples. This goes to prove that the composition of the gas is quite constant, and it agrees with the theoretical computation in showing the calorific power to be, in decimal units, about 1,000. In a study of the subject published in "Stahl und Eisen," March 15 last, Mr. Lurman, constructing engineer at Osnabrück, Germany, gave a mean figure of 879.6 calories. In either case the power does not seem so feeble as to preclude the use of the gas, when it is remembered that the gases made in the Dowson, Buire-Lencauchez and other generators and employed in engines give only about 1,300 calories, and that the long step downward to them from 5,500 calorie illuminating gas was taken with facility.

M. Dutreux proceeds to calculate the available power resulting from the direct utilization of producer gas. Assuming, as does M. Hubert, following the experimental data of Messrs. Kennedy, Hopkinson and Beauchamp-Tower, that the efficiency of the engine in indicated work would be 21.1 to 22.8 per cent. and its mechanical efficiency 80 per cent., the effective work would be 16.88 to 18.24 per cent. The aforesaid experiments were conducted many years ago with engines of eleven to seventeen horse power, while to-day much larger ones are frequently employed, and contracts of guaranty sometimes provide for an effective work of 23 to 24 per cent. If, however, the minimum figure, 16.88, be taken, and it be assumed that 50 per cent. of the gas is utilized in the engine, M. Dutreux finds that a furnace plant of 600 tons production per day, such as that of the Société, John Cockerill at Seraing, Belgium, should give 18,000 or 14,000 horse power, according as the characteristic ratio of the gas were .5 or .7. The steam power actually derived from the Cockerill furnaces is 2,300 horse power. It might be possible to obtain 3,000 in the same way, but from there to 14,000, or more, which the calculations indicate as a possibility with gas engines, is a long stride.

The first attempts to employ producer gas on a large scale

made in Europe have been undertaken in Great Britain, Belgium and Germany, the Scotch being, it is believed, the earliest in the field. The Belgians and Germans probably made their experiments independently of the British. The earliest patents upon the process taken out in England were by Messrs. Thwaite & Gardner. In the autumn of 1894 Mr. Thwaite proposed to Mr. James Riley, general manager of the Glasgow Iron and Steel Company, to apply it in that establishment, and a thirty effective horse-power "Acme" gas engined was installed by Mr. Thwaite in the Wishaw (Lanarkshire) furnace of that company to drive a lighting dynamo. A second installation of the Thwaite system has been made at the Frondigham Iron and Steel Works, near Doncaster. In the former case Scotch splint coal was used, and in the latter coke, and it appears that both installations have given entire satisfaction. The uniformity of operation of the engines would appear to be excellent. Mr. William H. Booth mentions having observed the engine at Wishaw for several hours, and that during that time he did not notice a single miss-fire. He declared also that the variations of the voltameter did not exceed 1.5 per cent. of their normal value. At Barrow 1,000 horse-power of the Thwaite system was to be installed. By this time a part of it, at least, should be in operation.

Several installations for the use of producer gas have been undertaken in Germany. Some of the German engineers have been bitter opposers of the plan, and this is the more remarkable in view of the degree of perfection attained in that country, both in gas-engine construction and in blast-furnace management. The question of dust in the gas has disquieted them a good deal. Mr. Lurman exploited, last winter, the results of one hundred and forty-three analyses and spoke discouragingly of the large quantities of dust present in the gases. He attempted to show that the producer gas of the Georg Marienhütte near Osnabrück, would deposit daily in the cylinders of a 100-horse-power engine twenty-nine liters of gas, occupying a volume of more than 100 liters. Mr. Greiner, who has published some results obtained at the Cockerill works, criticises this conclusion and maintains that the dust would probably not all be deposited in the cylinders.

With the use of six scrubbers described by Mr. Greiner, the dust of the gas at Seraing, although considerable, was removed to a perfectly satisfactory extent. The cylinder of the large engine there, after running for three weeks continuously, showed only traces of dust. It is even stated by Mr. Kraft, of the gas so purified, that it fouled the igniting apparatus less than illuminating gas, being almost free from hydrocarbons. M. Dutreux concludes that while the arguments of the German engineers look well on paper, it is possible to purify the gas as much as need be without being obliged to have recourse, as Mr. Lurman implies, to cleaning apparatus of the costly sort used for illuminating gas.

One of the German installations is at the works of Hoerde, near Dortmund, and its results are being kept secret. On a visit to the establishment M. Dutreux observed the apparatus designed for cleaning the gas. From a conduit coming from the ordinary purifiers and going to the boilers branches a pipe leading to a dry purifier of 13 to 16 feet in diameter and some 30 feet in height. In shape it is a vertical cylinder ending at the bottom in a truncated cone. After this purifier come four scrubbers arranged in battery; finally, a large reservoir or gasometer, 50 feet in diameter, which serves to store the gas, as in illuminating gas works. The engines are intended for electric work only. It is said that a triphase current will be generated and used to operate the locomotive transporting the ladle of metal from the blast furnaces to the steel works, a mile and a half away, the traveling cranes and the accessories of the rolls, but not the blowers. The engines make one effective stroke of the piston with each revolution. It is stated that the contract under which they were furnished by the Berlin-Anhaltsche Maschinenfabrik provides for the installation first of a 150-horse power experimental engine and then of a 600-horse power one if the results of the first one are satisfactory. If the large engine is successful another of the same model is to be put in. The arrangement of the 150-horse power engine is somewhat complicated, and, in view of the large size of the other engines for this early period in the history of the new application of producer gas, an unsatisfactory result would be by no means conclusive against its value for that purpose.

It is interesting to recall the first experiments that have been made at the Hoerde works, and which, without doubt, are also the first in all Germany. They are to be placed chronologically between those of Thwaite in Scotland and of Cockerill in Belgium. On October 12, 1895, the German Otto Gas Engine Company (factory of Deutz) put in operation an engine of 12-horse power, utilizing producer gas of the Hoerde furnaces. This engine had given 12.9 horse power with poor gas. The experiments lasted four months and a half, and gave entire satisfaction. The engine furnished 10.5 effective horse power at the speed of 200 revolutions. The indicated work was 11.75 horse power corresponding to a mechanical efficiency of nearly 90 per cent. The consumption of gas was 4 cubic meters per horse power per hour. The Otto Company did not receive the order for the new engines because they were unable to make quick enough delivery.

The Otto Company are making an important installation in Silesia, in the works of the Friedenshütte (Oberschelsische Eisenbahn-Bedarfs-Actien-Gesellschaft). The available power will be 1,000 horse power in four units, two of 300 and two of 200 horse power. A 16-horse power motor used there since September, 1897, has encountered some difficulty owing to the zinc dust which comes from the minerals employed.

At the famous Krupp works at Essen producer gas is being experimented with, as applied to a "Diesel" engine, but the results have not been made public.

In Belgium some extensive tests have been conducted at the John Cockerill works, and the results have been exploited with great freedom. The first engine—a "Simplex" made by Matter & Cie., Rouen—was put in operation December 20, 1895, and gave 8 horse power at the brake. The cylinder was 7.64 inches in diameter by 13.8 inches stroke, and the number of revolutions 210. With illuminating gas it gave 11 to 12 horse power. This shows that with producer gas an engine can give two-thirds the power that it would furnish with illuminating gas, although the calorific power of the latter is only 850 to 1,000 as compared with 5,000 to 5,500 for the latter.

It must be observed, however, that the proportion of illumi-

nating gas used to air admitted is one to six, while with producer gas the volumes are equal. Further, illuminating gas is used under a pressure of only about four atmospheres, while the producer gas employed in the engine at the Cockerill works was introduced at a pressure of ten atmospheres in order to obtain a good efficiency.

The fifth objection raised at the start—that relating to the necessity of using extremely large cylinders to obtain power—seems now to have been answered.

The difficulties of ignition have been completly surmounted by the use of powerful and permanent electric sparks. During some observations made in 1897 not a single miss-fire was noticed. This seems to answer objection three.

The engines at Seraine have been found to operate well under any variations of pressure that have taken place—even, if we do not misunderstand M. Dutreux, when the pressure has fallen below atmospheric; and it must be borne in mind that the first engine experimented with was used without a reservoir. This tends to refute objection three.

The last objection which remains for us to examine concerns the difficulty of starting. With the small engine used in the experiments at Seraing there was some sluggishness in this particular, and the engine did not always start immediately. In a large engine of 150 horse power there employed the result was accomplished by means of pinions moved by a hand lever and acting upon the fly wheel. M. Dutreux saw this means employed at Seraing in May, 1898, and a single man succeeded in starting the engine at the first trial in one minute and thirty-five seconds. It is certain that one may without difficulty apply an automatic compressed-air starter of the nature shown by Fielding & Platt, of Gloucester, at the Brussels Exposition in 1897.

The 150 rated horse power gas engine now being tried at the Cockerill works has a cylinder of 31.5 inches diameter and 39.37 inches stroke, and a speed of 120 revolutions per minute. It is said actually to have given 203 horse power at the brake.

M. Dutreux did not know of any works in France having an

installation of engines using producer gas. The Société anonyme des fers et aciers Robert, however, had arranged with Mr. Thwaite to install a 250-horse power engine at the furnaces of Outreau, near Boulogne-sur-Mer. A special system of purification adopted by Mr. Thwaite for coke furnaces was to be employed, and the available electric energy obtained was to be utilized at Boulogne and in the vicinity of the works.

In the Grand Duchy of Luxemburg producer gas engine installations have been made by at least two companies. At the Differdange furnaces a 60-horse power engine intended for lighting has been put in, and a $3\frac{1}{2}$-horse power engine to start it. These engines, although made by the same company that furnished those of Hoerde, give two motive strokes of the piston for each revolution, which may be taken to imply that Hoerde's results did not show the ultimate of perfection. A definite trial of engines at Differdange had not been made at M. Dutreux's writing. Experiments were being conducted by the Société des aciéries de Dudelange with a small experimental engine, having in view the production of 500 electric horse power.

M. Dutreux concludes that the use of producer gas in gas engines is now becoming practicable, and that although the gas engine, because of its high speed, is not easily adapted to driving blowers it is well fitted for generating electric power for distribution throughout iron and steel mills to supplant the appallingly wasteful little engines now employed—the parasites of metallurgical works.

CYLINDER RATIOS FOR COMPOUND ENGINES.

By George I. Rockwood.*

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The conviction that everything is now authoritatively settled about the design of the steam engine seems to have become a deeply rooted one in the minds of those who write text books on thermodynamics and heat engines; and, in a certain general sense, this conviction may be true. The steam engine of James Watt, considered as an automatic mechanism, was not different in any essential particulars from the steam engine of to-day. Even the compound engine was first proposed over a century ago. It is certain that the phenomenon of cylinder condensation was quite well understood at least three-quarters of a century ago, and the last word of theory may be found in Cotterill's treatise, "The Steam Engine Considered as a Thermodynamic Machine."

But though it may be admitted that it is next to impossible to devise anything really new in principle connected with the steam engine, this is very far from saying that actual steam engines to be had in the market to-day are all characterized by the same features, or that they may all be bought for the same price. One has but to examine the advertisement sheets of an engineering journal to be convinced that the problem of selecting an engine of the best kind, size, proportions and speed for a given duty is at present beyond rational solution. Shall the best engine be upright or horizontal? Single or double acting? Shall it have four valves with automatic drop cut-off, or two valves, or one positive valve? What shall be its speed? Shall jackets be used; and if so, on which cylinders? What about the real advantages of reheaters and superheaters? What shall

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be the boiler pressure? In most cases nowadays not one of these questions, so vital to the cost of the engine and steam plant, is necessarily answered by the conditions under which power is to be made, but its answer depends upon the opinion—or more likely, the prejudice—of the purchaser.

The truth is that while the modern steam engine is sufficiently complicated as a scientific and mechanical problem to account for the difficulty in estimating the relative significance of each element conducing to economy of steam, financial considerations—in other words, considerations of the net return on the total investment in the power plant—are even more fundamentally responsible for this uncertainty. Theory may show, for instance, a way to reduce a certain waste of heat by some elaboration of the steam plant; but, owing to the fact that "fixed charges" and the cost of repairs as well as of heat are also items in the total cost of power, this particular waste must perhaps be allowed to go on until the cost of the means for reducing it has itself been cut down. The cure may be worse than the disease.

The subject of this paper suggests one of the problems in the practical design of the steam engine still pressing for recognition and solution. Although great numbers of compound Corliss and marine engines have been built within the last twenty-five years, it is nevertheless a fact that next to nothing was known experimentally previous to eight or ten years ago in regard to the most economical ratio of cylinder volumes. The ratio was, and still is, fixed within narrow limits in all compound engines, whether built in this country or in Europe. Continental manufacturers have favored a proportion varying from the ratio 1 : 2.75 to the ratio 1 : 3.25. English and American builders have generally adopted a slightly larger ratio, namely, one varying from the ratio 1 : 3 to the ratio 1 : 4. A common rule is to make the diameter of the low-pressure cylinder two inches less than twice the diameter of the smaller cylinder. The explanation of this rule is found in the fact that an engine so proportioned avoids more than a very slight drop in pressure from that at the end of expansion in the smaller cylinder to the pressure at cut-off in the large cylinder, with reasonable ratios of expansion in each.

When "drop" occurs, it is because (at least the great engineering authorities have agreed that it is solely because) free expansion takes place—that is, a sudden enlargement of the volume of a gas without doing work against a piston, as in suddenly opening a cock in the pipe joining two cylinders, one full and the other empty of gas. Since free expansion of a working gas undeniably lowers the working pressure of that gas, any loss which such a lowering of pressure would entail may be obviated by preventing the free expansion. Hence, it is said, in a compound steam engine it is best to avoid "drop."

For thirty years this reasoning has controlled the design of the compound engine. During this time boiler pressures have been increased from an average of eighty or ninety pounds to an average of one hundred and fifteen pounds or more, without affecting the cylinder proportions generally used by engine builders. In this they have been supported by most authorities. In fact, so far as I can learn, but one authority—Carl Busley, Professor at the German Imperial Academy, at Kiel—would make any change in the cylinder ratio with different boiler pressures. He gives specific ratios for various boiler pressures as follows:

Pounds per square inch	60	90	105	120
Ratio	1:3	1:4	1:4.5	1:5

In the article on the steam engine in the Encylopædia Britannica, by Professor Ewing, may be seen the following statement: "Whenever a receiver is used, care should be taken that there is no unresisted expansion into it; in other words, the pressure in the receiver should be equal to that in the high-pressure cylinder at the moment of release. If the receiver pressure is less than this, there will be what is termed 'drop' in the steam pressure between the high-pressure cylinder and the receiver, which will show itself in an indicator diagram by a sudden fall at the end of the high-pressure expansion. This 'drop' is, from the thermodynamic point of view, irreversible, and, therefore, wasteful."

This statement by Professor Ewing is fairly typical of the confident language used by all of the most eminent authorities on the

steam engine when discussing the practical effect of "drop." It is a noteworthy fact that at the time when it was written, 1886, no one had ever made any experiments on actual compound steam engines to determine the effect of permitting "drop," even on an engine with a fixed ratio of cylinder volumes; still less had it ever occurred to anybody, so far as I know, to determine experimentally whether a gain or a loss would follow the adoption of larger cylinder ratios than that ratio which is small enough to prevent "drop" almost entirely. Since there were no experiments at hand to support the statement so positively made in the Encyclopædia Britannica, and therefore no truly scientific basis for it to rest on, one can but wonder at its almost universal acceptance both by theoretical and practical men. I am, of course, referring to the inference drawn from the last sentence quoted, to wit: "This 'drop' is, from the thermodynamic point of view, irreversible and therefore wasteful." The sentence itself is true enough; but the caution based on it is not logically connected with it, because it is too often the case that things, slightly objectionable *per se*, are inseparable companions of other things, which are necessary or indispensable.

I have sometimes thought that the impression left on the reader of "explanations" of the effect of "drop," of the sort generally found in text-books, is that "drop" produces a lowering of potential, as it were, without any compensating effect—such as would be produced by turning a stream of water on the receiver. Certainly the drop in pressure and temperature of the receiver steam produced by sudden and violent radiation or condensation is a totally different thing from drop resulting from intermediate expansion; but one might be excused for thinking that authorities lumped both kinds of waste in the same condemnation. In D. K. Clark's "Rules, Tables, and Memoranda," pages 854–855, occurs the following suggestive discussion of the influence of "drop:" "That the work of expanding steam is to be calculated from the expansion upon a moving piston only is obvious enough when it is considered that the steam may expand into an intermediate receiver and into intermediate passages without doing any work on a piston, whilst at the same time the pressure falls or 'drops' as

the volume is enlarged. Under these circumstances the second cylinder receives the steam at a lower pressure and in larger volume than it has when there is no intermediate expansion and fall of pressure, and there is less work done, whilst the ratio of active expansion is necessarily reduced. If the second cylinder, however, be enlarged in capacity in proportion to the enlargement of the volume of the steam and the fall of pressure by intermediate expansion, the ratio of expansion and the work done in it would remain the same."

These quotations, considered by themselves, would commit Clark to the common belief that "drop," produced by intermediate expansion, causes a serious waste. He goes a little farther in the right direction than others have done, however, in the suggestion that the waste occasioned by "drop" may be balanced by enlarging the second cylinder; but he does not, in this immediate connection, draw attention to the fact that the loss in pressure of the receiver steam, due to the practice of taking more steam by volume from the receiver than it gets from the high-pressure cylinder, is accompanied by an increase of work in the high-pressure cylinder. That is, the back pressure in that cylinder is reduced at the same time with the reduction of the initial pressure in the low-pressure cylinder. Hence the loss of power occasioned by receiver expansion, though it exists, is really very much less than Clark implies in the quotation, and with high boiler pressures and moderate amounts of "drop" is, even from a thermodynamic point of view, quite insignificant. Again, it is not the statement of fact which the authority quoted makes that I take exception to, but his inference of the bearing of that statement on the design of the actual compound engine, and also, in this case, the fact that he here leaves unsaid that most important modifying consideration pointed out above. This is not to say, however, that Clark did not himself point this out in another place; but had he done so here he would not have left so unqualified a feeling of distrust toward free expansion. It simply illustrates the confusion of mind of authorities as well as builders with reference to this subject.

I have referred to the universality of the belief in the error in

permitting "drop" in the receiver of a compound engine, and to the lack of any foundation for this belief in direct experiment on an actual steam engine. I have shown also that this belief was based on considerations derived from pure theory—in fact, from the science of thermodynamics. I myself hold, as a result both of speculation and of experience, that while the waste attributed to "drop" is a reality and its amount may be computed if the amount of "drop" is known, such waste is not necessarily a controlling factor in determining the ratio of the cylinder volumes. Indeed, it is incomprehensible to me how the distrust of receiver expansion grew to such proportions and became all powerful in the design of compound and triple-expansion steam engines. Perhaps it is the result of the idea widely held not many years ago that the real cause of "drop" was simply initial cylinder condensation and clearance in the second cylinder. The receiver space was said to be as harmful as so much extra clearance, and it is wonderful what efforts and oddities of design were put forth, especially in the design of pumping engines, to lessen the distance between the exhaust port of the small cylinder and the steam port of the larger cylinder, with a view to minimizing the alleged uneconomical influence of a large receiver volume. I believe this view is all wrong, and probably most engineers would agree with me; yet it is apparently still held in some high places.

In a leading article on "Intermediate Expansion" in "The Engineer" (London) no longer ago than 1891, occurs this passage: "All intermediate receivers, port spaces, clearances, etc., mean intermediate expansion." In the same breath the writer goes on to say, ". . . the size of the intermediate receiver has no practical influence on the performance of an engine!" It is pretty well demonstrated that what is ordinarily called clearance is a chief cause of preventable waste; and if the receiver is really to be classed in the same category with, and as an addition to, clearance, its great size would inevitably affect the steam consumption very adversely, which, as "The Engineer" says, it does not. In the issue of the second of December, 1898, "The Engineer," in a leading article on "Compression

in Steam Cylinders," reverts to this same thought in these words: "Nothing has been said about compression in compound engines. There is, however, no room to think that the effect will be materially different, whatever the number of cylinders used, at all events so far as the high-pressure cylinder is concerned; both the others work with maximum clearance in the sense that the receivers become *ipso facto* part of them twice in every revolution." Yes, but only during admission, and in the usual cross-compound engine with large reheating receiver, the fluctuation of the receiver pressure, due to the discharge of steam into the low-pressure cylinder, is hardly greater than that of the boiler supply-pipe pressure, due to the discharge of steam into the high-pressure cylinder. In the one case, the piston of the first cylinder pushes out a cylinderful of steam into the receiver, and a somewhat larger volume is discharged therefrom into the second cylinder; but in the other case, the boiler does not make steam as fast as the high-pressure cylinder withdraws it during the period of admission, but only one-third to one-fifth as fast, depending on the point of cut off. Both cylinders therefore work under conditions practically identical, and neither boiler nor receiver can be properly classed as additional and objectionable clearance space.

Nothing but confusion can result from associating intermediate receivers in the same category with clearance spaces. It is especially incorrect to urge that "all intermediate receivers, port spaces, clearances, etc., mean intermediate expansion"—that is to say "drop." "The Engineer" has, however, been for many years a consistent advocate of the idea that "drop" was a very small influence against the economy of a compound engine.

Quite a little has been done of late years in the way of experiment to find out the effect of "drop" in marine engines. A paper was read in 1893 before the Institution of Naval Architects of Great Britain, giving the results of a feed-water trial of a triple-expansion engine with and without its intermediate cylinder. The result was very much in favor of the three cylinders, as might have been predicted under the conditions of operation. The loss due to an enormous "drop" was the cause of the inferiority of the

performance of the compound engine. With a boiler pressure of 125 pounds the M.E.P. of the first cylinder was 100 pounds! That is to say, there was next to no expansion of the steam before release in that cylinder. This paper was considered by many engineers at that time to supply incontestable evidence of the wastefulness of intermediate expansion. That is, because a drop of 100 pounds caused a loss, therefore all drop, under all circumstances, should be avoided. But this is not the only source of information on the performance of compound marine engines in which considerable "drop" is allowed.

Mr. H. Crompton Ashlin, Consulting Engineer, of Liverpool, declared in a letter published in the "The Engineer," dated April 3, 1893, that it has been practically known for years, to some Liverpool engineers at any rate, that high-pressure compounds can be worked at 150 to 160 pounds pressure with as good results in consumption as the best triples worked at the same pressure. In a later issue Mr. Ashlin gives a short history of his efforts in this direction. His firm had at that time converted the engines in some eight steamers from old-style compounds into high-pressure compounds, the results being that, "whilst maintaining the original speed, the consumption of coal has been reduced to the same amount as would have been used if triple engines had been substituted."

Let us consider, now, what are the causes of "drop," and then, what are the advantages which accompany its moderate use.

The causes of "drop" are of two kinds. The first kind is the one we hear the most about, namely: "intermediate expansion." When more steam by volume leaves the receiver than is put into it, per stroke (presupposing that no steam is either made or condensed in the receiver itself), the receiver pressure is bound to be less than the pressure at release in the high-pressure cylinder. This is simply saying that the pressure of a gas or vapor at constant temperature bears a fixed relation to its volume. The other causes of "drop" are cylinder condensation and clearance in the low-pressure cylinder. Suppose a receiver compound engine had neither clearance or condensation in the low-pressure cylinder. There might still be any amount of "drop" if the cut-off

on that cylinder were lengthened enough. On the other hand, if the cut-off were just adjusted right to prevent any "drop" in such an engine, and then that cylinder were endued with both the usual amount of clearance and of condensation, probably at least fifteen pounds of "drop" would be the immediate result. Again, this even then could all be prevented by making the cut-off earlier in the stroke. It is thus obvious that the point of cut-off may be a cause, or it may be a corrective, of "drop." But the point of cut-off is dependent on other considerations than its influence on the amount of "drop." As a matter of fact, it would be desirable to have the cut-off take place late in the stroke, were it not for the loss from excessive free expansion thereby involved, because this would reduce the range in temperature of the low-pressure cylinder walls, and hence would reduce the loss from initial condensation in this cylinder.

It is evident from the foregoing that unless the best point of cut off, estimated solely with reference to the waste by initial condensation, happens to coincide with that particular point at which "drop" would be entirely prevented, a compromise must be made between the gains on the one hand, to be made by lengthening cut off and thereby reducing condensation, and the loss, on the other hand, thereby incurred from free expansion. It does happen that with cylinder ratios in the neighborhood of 3 : 1 no such compromise need be made, because both considerations suggest the same point of cut off; but with larger cylinder ratios, such as 5, 6, or even 7 to 1, some "drop" is inevitable, and it becomes a question of just where to locate the points of cut off in both cylinders so as to secure a minimum net loss from clearance, intermediate expansion and initial cylinder condensation. If "drop" is accompanied by a reduction of initial condensation in the second cylinder in amount sufficient to overbalance the waste of power by intermediate expansion it is, at least, no detriment to the coal consumption to allow that much "drop." Moreover in stationary engine practice few engines drive perfectly uniform loads. Nearly all light, heat and factory loads are decidedly variable, and engines most suitable for driving such loads are compound condensing engines working with considerable "drop,"

because this permits a widely variable cut off in the second cylinder without either looping at the end of expansion in the first cylinder or materially changing the receiver pressure. It is seen, therefore, that the advantages of "drop" are of both a thermal and a practical nature.

Having now dealt at some length with the subject of intermediate expansion and its relation to the subject of this paper, let us proceed to consider the general theory of the compound engine. As an abstract proposition, the highest economy to be realized in an engine of any type is the result of two conditions—using a volume of steam at the highest possible pressure, expanded the utmost number of times. In practice, both the pressure and the number of expansions are limited by practical circumstances; the pressure, by the increase in cost and maintenance of the boilers and piping as the pressure is carried up, and the total ratio of expansion by the increase in the waste due to cylinder condensation, friction and repairs. All authorities, I believe, are agreed that there is a certain minimum number of expansions allowable in any one cylinder of any type of engine. This number is between four and five. Now, as it happens that practically no "drop" will occur in the receiver of a compound engine having a cylinder ratio of about 3: 1 and between four and five expansions in each cylinder, the custom has been, and still is, to limit the total number of expansions in such an engine to twelve or possibly fifteen. And a steam pressure of 115 pounds is about as high a pressure at it is necessary to have with such an engine to get the best economy. A higher pressure will enable the engine to do more work, but the number of expansions would remain the same, and hence the rate of steam consumption would hardly be affected at all thereby. So, if higher pressures are to be used with the object of improving the economy of the engine, the only way to do it, according to the received theory, is to add another cylinder in series. The average boiler pressure in use with the triple-expansion engine is 150 to 160 pounds. With such a pressure and with cylinder ratios of usual proportions—say 1 : 2.75 : 6.5—the number of expansions allowed in each cylinder is less than the four or five mentioned

above. It is more likely to be 2.5 to 3. This is because 150 pounds is not nearly high enough to permit the larger number without developing too little pressure at release in the low-pressure cylinder.

The triple-expansion engine, or shall I say the multi-cylinder engine—how grand the name sounds!—holds a firm place in the affections of the college-bred engineer. What a complicated thing it is! How glorious to be able to say, "I comprehend it. I can design it and make it go without any 'drop.'" He longs for the time to come when, in the natural evolution of the multi-cylinder idea, he may have a chance of designing a quintuple, or even a sextuple, steam engine. Unfortunately for this vision, recent developments in the design of the steam engine for stationary work seem to put the time of its fulfilment yet a long distance off. In the year 1891 "The Railroad and Engineering Journal" published an article, written by myself, with this title, "How Many Cylinders Will It Pay to Introduce in the Multi-Cylinder Engine?" This was a very brief discussion of the theoretical and practical utility or uselessness of the intermediate cylinders of a multi-cylinder engine, and was written before any experimental data were available to reinforce the position taken, which was that these cylinders were of no theoretical or practical advantage as aids to the economical operation of the engine. At that time a triple-expansion engine was being constructed, and the opportunity thus presented of arranging the intermediate cylinder so that the engine could be run without it was embraced, and the following year numerous tests of this engine, with and without its intermediate cylinder, appeared to show that on that engine the second of the three cylinders was of no advantage. This was with reference to the economy of producing an *indicated* horse power. The friction of its piston and valve gear, not to mention the interest and fixed charges on the investment, made a considerable loss per *delivered* horse power.

Since the tests of this triple-expansion engine were made, eight other large engines, built by the Wheelock Engine Co., on lines which these tests indicated to be correct, have been tested by the

following engineers: Two by Prof. Geo. I. Alden, A. S. M. E.; one by Francis W. Dean, A. S. M. E.; three by Geo. H. Barrus, A. S. M. E., and two by myself. In all, the same builders have built about 25,000 horse power of these compound condensing engines, and each engine was sold under agreement to use not over 12½ pounds of dry steam per I.H.P. per hour. In some cases the engines were not at first complete mechanical successes, and in one case this extended to the tightness of the valves and pistons, etc., causing a greater steam consumption than that guaranteed. In all of the other cases, however, so far as I am informed, the guarantee was surpassed. The very best performance of any mill engine which has been tested by recognized and competent experts is one of this type running at the mills of the Grosvenor Dale Company, and tested by Mr. Barrus, who published his report in "The Engineering Record," November 20, 1897. The steam consumption was 11.89 pounds total per I.H.P. per hour, and the coal consumption was 1.18 pounds! The average I.H.P. developed by the engine during the test was 660. If such a result as this had been announced over the signature of Mr. Barrus or any other expert a very few years ago, he would have simply forfeited his reputation for veracity for the time being. I believe, nevertheless, that a pumping engine of largest size, working with practically no clearance, with steam at a boiler pressure of 180 pounds, and a cylinder ratio of 8:1, would give the horse power on a consumption of less than 11 pounds of steam, and a coal consumption of one pound per I.H.P. per hour.

To appeal to the best recorded performance of any type of engine working under every-day conditions as to tightness of valves and pistons, as to clearances, and as to the operation of the jackets, etc., as a proof of the superiority of that type as compared with all other types, while being a thoroughly practical, is also a distinctly unscientific, manner of procedure. Besides introducing possible errors or deviations from the very best result of which that type is capable, due to unknown amounts of leakage, etc., another error to which all tests are open, namely, the instrumental one, resulting from the fact that the different engines tested are situated in different parts of the

world and are tested by different experimenters whose personal equations are unknown, this error, I say, makes such a comparison of very secondary importance as a guide for the future. If some one having the opportunity would test the most economical triple-expansion engine anywhere to be found, working with a boiler pressure of 160 pounds, and a vacuum realized in the low-pressure cylinder of 13½ pounds, both with and without its intermediate cylinder, and have as his object to determine the heat required per brake horse power per hour, by this engine in each case. I think, but I do not, nor does any one else know, that the result would show the advantage to lie with the simpler form of engine. Such a comparative test would be a truly scientific one, and the knowledge thus obtained would be definite and compel our assent to its authority.

In the absence of such a perfect series of tests as I have outlined, we may, at least, be interested in, and allow our judgments to be influenced by, the tests made on the comparatively uneconomical and, because of its small size, low boiler pressure and poor vacuum, unrepresentative triple-expansion experimental engine in the laboratories of Sibley College, Cornell University. These tests are reported and very fully discussed in a paper in Vol. XIX of the Transactions of The American Society of Mechanical Engineers. It would be impossible to quote from the language of this paper and do justice to it within the limits of my time, and I will simply call your attention to it and quote from Mr. John H. Barr's discussion of it the figures which he presented as the water rate of this engine, run both as a triple and as a compound.

JACKETED ENGINE.

Triple	I.H.P., 141.4;	water rate, 15.37
Two cylinders	I.H.P., 152.0;	water rate, 15.58
Triple	I.H.P., 45.6;	water rate, 17.70
Two cylinders	I.H.P., 47.7;	water rate, 16 80

The compound does as well as the triple on heavy loads, and better on light loads. This paper, together with one by Mr. F. W. Dean, entitled "Trials of a Recent Compound Engine With a Cylinder Ratio of 7 : 1," cover about all the philosophy and data that are at present known on this subject.

The answer to the question, What is the best cylinder ratio for a compound engine? depends upon the facts with regard to the loss by cylinder condensation and the loss by intermediate expansion. Little is known specifically about these facts so far as they appertain to these recent compound engines which work with high steam pressures and have very small high-pressure cylinders. As I have shown, all that we know is that high ratios and high pressures beat low ratios and low pressures; and, with the exception of the analysis by Dr. Thurston of the Sibley engine tests, we have no experimentally-derived knowledge of the details of the saving process. This analysis, so far as it goes, bears out the view which I originally entertained of the essential incorrectness of the received theory of the action of steam in a compound and in a triple-expansion engine. The deduction from that theory has been that the thing to aim at in the design of either type of engine was, besides eliminating "drop," to so proportion the cylinders as to have each cylinder do an equal proportion of work, and have the steam work through an equal range in temperature in each cylinder.

Almost the first thing that was said when the proposition to do away with the intermediate cylinder in triple-expansion stationary engines was made was that the great increase in the range in temperature in the first cylinder caused thereby would greatly increase the loss by cylinder condensation in that cylinder. My answer to that was that even if there were more condensation thus effected in the first cylinder, this would not matter unless there was such a great increase in condensation as to exceed in quantity that in the low-pressure cylinder. The singular fact is developed by Dr. Thurston's analysis, however, that the quality of the steam at cut-off in the first cylinder of the Cornell engine when operated without its intermediate cylinder was actually better than when the range in temperature was lessened by using that cylinder, and his explanation was that this was the direct result of the sudden drop in pressure at release in the first cylinder of the compound, which did not take place in the triple. Furthermore, the improvement in the quality of the steam caused by "drop" was about equal in both the high

and the low-pressure cylinders, and was most noticeable with the most "drop!"

These experiments, at all events, make it perfectly plain that cylinder condensation does not depend directly and solely on the range in the temperature of the steam. The extent of the surface exposed, and the amount of "drop" allowed, have at least as much to do with it.

I will bring my remarks to a close by saying, finally, that I do not desire to see the triple-expansion engine discarded absolutely and for every purpose. I believe it is indispensable at sea for mechanical reasons; also for certain kinds of direct-acting steam pumps, working without cut-off in individual cylinders. But for stationary power-plant engines the most economical engine at present practically possible, all things considered, is, in my judgment, a cross-compound engine, working with a boiler pressure of 180 pounds, a vacuum of 13½ pounds, a receiver pressure of 8 pounds, and a cylinder ratio of 8 : 1.

ROPE DRIVING.

[From "Quarterly Digest of Physical Tests."]

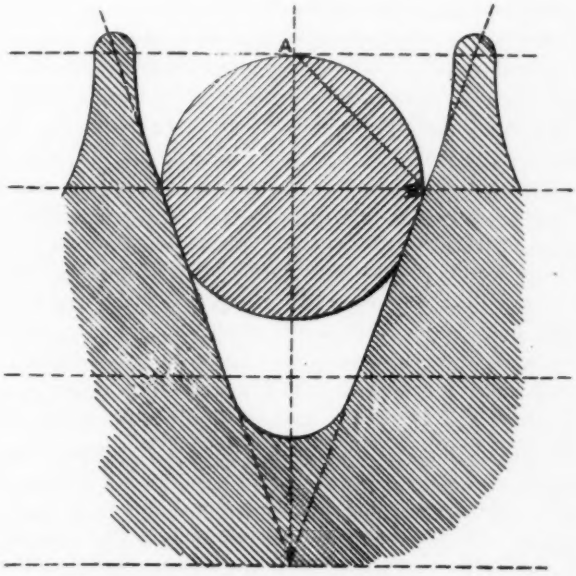
The use of ropes in dynamo driving has been far from common in the past, but is estimated by some as likely to be more common in the future. The truth is that the dynamo differs much from most pieces of machinery of equal bulk. An armature of small size puts an immense resistance against the driving force, and most armatures have very small momentum as compared with the power absorbed in the driving of them. Yet in electrical work, perhaps not in lighting, but at least in traction and other power transmissions, there are apt to be very great sudden fluctuations of the power absorbed. Where there is no fly wheel the stress thus produced is transmitted immediately to the furthest point of the machinery, and in direct-connected engines, the stresses which come upon the crank-shaft are very severe, and quite sufficient to account for the many failures which have taken place in such shafts. The stresses make no outward or visible sign other than any slowing down of speed they may bring about. In case of belts or ropes which are placed between an engine and a dynamo, and are called upon to suddenly take up or give out stresses of large amount, the fact is made prominently visible by the wave which is thrown into them, and heavy ropes apparently make a sudden leap which is really dangerous. This points to the necessity of using fly wheels on armature spindles exactly as they are used in cases of direct driving. But there is another aggravating cause of trouble. It is frequently the case that dynamos are placed considerably below the engine. This is a mistake. When so placed any wave thrown off the upper side of the driving rim has all its centrifugal and upward tendency allowed full play. When the dynamo is above and a wave is thrown off from the fly rim, the effect of gravity tends to pull the rope down against its centrifugally applied upward wave. As a result the rope traveling

upward to the dynamo pulley is urged by gravity against the face of the driven pulley, whereas, in the case of the downward-moving rope, gravity is opposed by the inertia of the rope, and the wave may reach the driven pulley and get half around it before it gets down to its groove. Wherever possible the slack side of a rope should travel uphill. In short, it is unfair to blame ropes for the fault in design which is evidenced by the neglect to apply a fly wheel. Otherwise the important points in rope driving are the rope diameter, the ratio of rope to pulley diameter, the form of grooves, the distance apart of shaft centers, the material of the ropes, their velocity and the unit stresses in them.

Messrs. W. Kenyon & Sons, of the Chapelfield Ropery, Dukinfield, who have made a special study of the subject, and are the makers of the patent inter-stranded rope which bears their name, consider that though the diameter of the smallest pulley should be at least thirty times that of the rope for cotton, and forty-five times for hemp, it is nevertheless desirable to make the driven-pulley diameter fifty times the rope diameter, and the driving pulley one hundred and fifty times. As to this, however, much must hang upon other considerations. In the early days of rope driving, ropes were commonly two inches diameter, but thinner ropes are stronger per unit of sectional area. Large ropes, however, have greater durability, and becomes less worn in proportion to their weight than do thin ropes, and the general result of now many years' experience has been to fix upon $1\frac{1}{8}$ inch as a happy medium. For large powers, seeing that ropes of large diameter will give a much greater power per unit of breadth of face of rim pulley, it is clear that the length of a heavily loaded shaft can be kept to a minimum by using large ropes. Large ropes also hang better and in more even curves, and we think that nothing should be used of less size than one and one-half inches where possible, and this would call for 45-inch driven pulleys in order that the minimum ratio of pulley diameter to rope diameter may be maintained.

The form of the groove is a matter that requires consideration. Continental makers often make the bottom of the groove flat. English practice is to make it round. This is not a matter of

much importance. What is important in the matter of grooves is that every groove shall be of the exact same form, and they should be so made that the ropes wedge into and release themselves without much friction. Moreover, the ropes must not touch the bottom of the groove. From 40 degrees to 45 degrees is a usual angle to adopt. Messrs. Kenyon, to whom we are indebted for the annexed copyright method of designing the grooves, use an angle of about 41½ degrees, obtained by the construction shown in the annexed figure, as follows:



1⅛ Diameter Rope, Full Size.

Draw the circle of the rope with intersecting vertical and horizontal axes. Draw the cord, *a b*. From the center of the rope mark off on the vertical line a distance equal to *a b*, this will give the center of the root circle. Next mark off a further distance equal to *a b*, this gives the point of intersection of the sloping sides.

Draw these sloping sides through the ends of the horizontal diameter of the rope and carry them forward till they cut the dotted line drawn horizontally across the top of the vertical diameter of the rope. The intersection is the center of the narrow flange curve. The flanges are made thin and joined by an easy curve to the inclined sides of the grooves; but this curvature should cease as shown at a distance about equal to $\frac{1}{6}$ the rope diameter above the horizontal diameter of the rope, for it is of importance that the groove sides should be flat and not curved or they will prevent the rope from bedding itself to shape. It will tend to revolve, and a rope which rotates about its own longitudinal axis wears more and never assumes the solid shining appearance which characterizes a well-wedged rope. We do not say this is the sole cause of rotation, but it is believed to have an important influence and, therefore, grooves should have flat sides. In the diagram the flattening of the rope circle by the inclined sides about represents what actually takes place in shaping a rope to its groove. Any angle sharper than about 40 degrees would cause too severe a wedging action; any more obtuse angle than 45 degrees would too seriously reduce the wedging action. It must be noted that as a rope enters a groove slack and leaves it stretched, and therefore so much smaller in diameter, the tendency is for it to occupy a lower place in the groove as it nears the point where it leaves the pully again. The rope lies, as it were, between the sides of a very long pair of inclined planes, and it is thus held from slipping by this longitudinal wedge action as well as by the frictional grip of the inclined sides. The base curve of the groove is of course simply made to touch the sloping sides; this fixes its radius. Sometimes the vertical portion of the flanges is omitted, and the sloping sides are simply joined by a curve which does not always extend so high as the top of the ropes. These do not give quite so great safety against jumping of the ropes from groove to groove. To be easy in working, ropes must not be too short, the distance apart of the shafts being conveniently three times the joint radius of the driving and driven pulleys. Any excess over this is apt to allow too much sag in cases of horizontal driving, and generally too great

length is not desirable, especially in dynamo work, as the large amount of slack is a source whence a sudden change of stress may give rise to wave motion and shock. Too short a distance between shafts is, however, undesirable, especially where the pulleys differ considerably in diameter, as it reduces the grip arc on the small pulley to what may prove too small to secure a proper grip.

The length given is, therefore, a fair average. In a factory of several floors the ropes to the upper floors are obviously much longer than the others, but the distance in plan is not necessarily so, and the sag of the slack side is not therefore excessive. Direct vertical driving is to be avoided where possible. When a nearly direct vertical drive is unavoidable allowance has to be made for the fault by using more ropes to the extent of 15 or even 20 per cent. or more, while, where the slack side in a horizontal drive is the lower side, a percentage of 10 to 15 per cent. should be added to the number of ropes to make up for the less desirable arrangement. In calculating the power that a rope will transmit, it must be remembered that there is a wide margin of strength, but for ordinary speeds the horse power that a rope may be safely made to transmit may be set down as

$$\text{H.P.} = \frac{d^2 s}{5{,}000},$$

where d is the rope diameter in quarter inches, and s is the rope velocity in feet per minute. Thus a $1\frac{3}{4}$ rope at 5,000 feet figures out at nearly 50 H.P., and though speeds of 6,000 and even 7,000 may be employed, it must be remembered that for the stresses used in practice 5,000 feet per minute is the maximum velocity beyond which the stresses due to centrifugal tension increase at a faster rate than the increase of power. Beyond 5,000, therefore, a rope is really less efficient. The limits of practice are conveniently from 2,000 to 6,000 feet velocity, but there is no objection to slower speeds when needful. One should aim to get a speed of 3,600 to 4,800 where possible. Between these limits a rope has practically an equal efficiency. As regards material the first driving ropes employed in heavy driv-

ing were of hemp, because it was in Dundee that rope driving was first employed. Americans use manilla very much, but manilla is a very rough fiber and works its own destruction, and nothing has proved so good as cotton. Egyptian and American cotton are those most suitable. There is practically no difference between them.

As regards the question of electrical driving it may be thought that an elastic rope which has a considerable slack will be more objectionable than a tighter rope. In this respect we understand that arrangements are being made to test the properties of Rhea fiber as a material for driving ropes. Rhea fiber, which is the strongest fiber known, and is a fine, smooth fiber of great length and capable of being spun fine like cotton, has exceeding little elasticity and would therefore make ropes that would stretch very little, and would, at the same time, be as free from internal friction as cotton.

The question of strands is one of importance. Any one who will draw three circles in contact, and four circles in contact, will see at once that there is only one arrangement for the three circles in a rope. With a four-strand rope two opposite circles may touch, and the other two may not touch, and a four-strand rope tends to become irregular in shape. There is, therefore, no reason for having more than three strands to a rope. They form a more solid rope than any other number. A four-strand rope requires a core to help it in its proper laying. A core makes a rope stiffer, and, moreover, it is very apt to take above its share of load. This may break it, and the vacant gap between its broken ends is occupied by the rope getting out of shape and the space becoming filled by one of the strands. Other numbers of strands also require a central core, and are exposed to the same liability to get out of shape as the four-stranded rope, and three strands have now become the standard.

With a material like cotton, the pliable nature of the strands allows them to so interbed themselves as to practically fill solid the center space, and, after some time of working, a rope which has become bedded assumes an almost triangular shape and gets hard and compact, and, if suitably dressed with a minimum of

dressing, becomes polished on its bedding sides and runs almost like an iron bar in appearance. Dressing should only be very sparingly applied, and on no account in sufficient quantity to soak the rope. Dressing contains plumbago, and while this helps the rope to become polished the liquid portion of the mixture is supposed to be present simply in sufficient quantity to lay any fluffy ends. A mixture much used on machine ropes is one of plumbago and treacle or syrup. Oil must not be used. It is usual when making a cotton rope to lightly serve with plumbago and tallow the outer surface of each strand before laying up the rope, but this is all that is needed; there should be no composition between the individual threads.

It may be added, in regard to speed and the folly of running ropes, by intention, at specially high speeds, that even the speed of maximum efficiency is really not the most economical speed. It allows of the use of minimum rope pulleys, but the wear of a rope is a result of its speed, and, at 5,000 feet the wear is 25 per cent. additional to the wear at 4,000 feet, yet the working capacity of the rope, alowing for centrifugal stresses, is under 3 per cent. more at 5,000 feet velocity than at 4,000 feet. Indeed, the wear may be doubled by raising the speed from 2,500 to 5,000 feet, and less than 40 per cent. will be added to the capacity.

The Lancashire practice in rope gearing has so fixed the ratio of working stress in the rope to its weight per foot and centrifugal stress that the velocity of maximum capacity coincides with the 80 feet per second usually considered as the maximum safe velocity for a cast-iron rim. The maximum velocity has been found to produce the best results, but here again the results so obtained are merely a coincidence. They are good because of the excellent fly-wheel effects which accompany high rim speeds, and not necessarily because of the high rope speed, and, speaking generally, there have always been so many considerations in the whole question of main driving, that certain results have been very commonly attributed to wrong causes. Ropes have been run with perfect satisfaction up to speeds as high as 7,000 feet per minute, developing, per 1¾-inch rope, some 93 H.P. This implies not simply an increase in the centrifugal ten-

sion, but also in the working tension, and is not to be recommended on the score of durability, because at that speed the tension on the rope is 427 pounds due to centrifugal tension, 438 due to working side pull, and probably 86 pounds due to the slack side tension, a total of 950 pounds, which is quite 50 per cent. more than usually allowed.

Early rope installations attempted to employ ordinary shaft bearings, and a good deal of trouble naturally followed with heated necks. The high rotative speeds coupled with the heavy side pulls of the ropes, and the absence of the vibration which was set up when toothed wheels were used, combined to cause trouble, and bearings for rope-pulley second-motion shafts have grown in length up to five diameters of the neck. To prevent bending and enable a shaft to be of minimum diameter, the supports have been placed close to the pulleys, or have been made double, with enlarged central diameter of shafts, and continuous oiling pumps are fitted to maintain a constant flow of oil over the necks, the pumps being driven by bands from the shafts themselves, a pump and an oil box and circulating pipes being fitted for each bearing. The necessity for large area of bearings arises from the steady pull of the ropes and the very continuous pressure upon the brasses tending to exclude oil. Brasses need to be suitably channeled to lead the oil in, but there should be no through oil hole drilled into the oil channels of the loaded brass, nor should the channels extend to the ends of the brasses whereby a too free escape of oil is allowed.

In the question of multiple independent ropes or of the single rope reduplicated, there are, of course, arguments to be advanced on both sides, but the weight of evidence and experiene is in favor of the multiple system. With this system the grooves of the driving and driven pulleys are exactly opposite to each other, and this is not the case in the system of reduplication where the grooves have a lateral relative displacement of half a groove. The rope entering No. 1 groove of the driving pulley leaves No. 1 groove of the driven pulley it is true, but the rope as it enters the No. 2 driven groove has left the No. 1 groove on the driver, and finally when every groove is followed out the rope has to be brought back to the starting point right across the full breadth

of the driving drum, and there must be a carrier pulley for this purpose.

The angular direction of the ropes relative to the grooves causes lateral rubbing and tends to cause the ropes to revolve upon their own axes. This tendency is mischievous, for when a rope revolves it never beds itself to shape in the grooves, and will not have the endurance of the bedded rope. Where the single rope is employed it is wound the necessary number of turns round and round all the pulleys to be driven, every turn, of course, passing round the main drum. Thus, with the grooves in the main drum and four equal driven pulleys, each driven pulley takes four laps of the rope, which also is carried once round a sheave carried by a tension carriage. The advantage of this system lies in the ability to regulate the slack side tension to a uniform minimum in each lap of rope, and it is more suitable also for vertical drives, the tension carriage serving to take up all the surplus slack which would otherwise cause the ropes to slip. But for most ordinary straightforward work the independent ropes are preferable. It is probable that the system of reduplication, more used in America than here, was introduced to America from Germany. English arrangements of machinery are rarely made of the style which calls for direct vertical driving, and efforts are generally made to secure a sufficient horizontal distance between shafts to allow of comfortable working with not unduly tight ropes. In such cases the system of separate ropes has so many advantages over the reduplicated single rope that it is not worth while considering for such situations a system which requires the complication of a tension carriage. In dynamo driving, especially where the dynamo is provided with an adjustable base, allowing an unduly slack set of ropes to be tightened up, the independent rope system is freed of the one fault that might be urged against it.

When the strength of a rope is considered, it is obvious that if a cylinder of parallel fibers or yarns be twisted together, the external yarns will be made much shorter than the inner ones, so that in a strand thus simply twisted together, the outer yarns will be exposed at the same time to the heaviest stress and the greatest amount of wear. The tendency of this is to cause a

rope to wear much more quickly than it would otherwise do. If we take a three-strand rope, each strand is equally situated as regards position and twist, and as regards the strands there is no weakening. Now, Messrs. Kenyon & Sons, recognizing the evil of unequal stress, brought out their interstranded rope. In this rope each of the three strands is composed of a considerable number of smaller strands coiled layer by layer upon an inner set of strand. If a piece of rope be cut off, say exactly four inches long, each of its three strands will measure a trifle over four inches, but they will be equal because they will all be equally placed in the rope. If now one of these strands be peeled, its outer layer can be removed and will freely leave the inner portion; this may in turn be peeled, and so on, one layer after another being removed, and if the little strands of each layer be measured when laid out straight, it will be found that those first peeled off will be the longest. This is correct, because they have as many turns per foot length of rope, and are wrapped round a larger circumference. In the patent interstranded rope, therefore, every small strand has a length suitable to its place in the rope and takes its proper stress, and every thread in the rope follows its proper course and does not vary from its position throughout the whole length of a rope, unlike where a rope strand is simply composed of so many thousand threads twisted together with less attention to this important point.

In tests made by Kirkaldy a rope of $1\frac{1}{4}$-inch diameter broke at 12,017 pounds.

This system of manufacture facilitates the making of ropes any length. Numerous ropes have been made 4,000 feet long without a joining, and from $1\frac{3}{8}$ to $1\frac{3}{4}$ diameter. In fact, the limit of length is that of convenience of carriage of the bulky roll.

In splicing a rope a special man ought to be employed, and at least seventy-two diameters of a rope ought to be the length of a splice. Carefully spliced, with due regard to the gradual tapering down of the strands, a splice neatly finished is very little less in strength than the body of the rope, and after a short run it is often impossible to find the spliced portion. The approximate weight of a good cotton rope is as follows:

Diameter of rope.	Weight per foot.	C.
$1\frac{1}{4}$ inches,	0.5 pounds,	64
$1\frac{3}{8}$ "	0.6 "	53
$1\frac{1}{2}$ "	0.72 "	44
$1\frac{5}{8}$ "	0.844 "	38
$1\frac{3}{4}$ "	0.98 "	33
2 "	1.3 "	25

A good figure to remember being that a $1\frac{3}{4}$ rope weighs 1 pound per foot, and other sizes in the ratio of their diameters squared. The coefficient, C, is useful in determining the stress due to centrifugal force for any velocity, the square of the velocity in feet per second divided by C giving the stress in the rope due to speed, and serving to calculate the stress for any speed from which the margin remaining for useful work can be deduced. Thus for a $1\frac{3}{4}$ rope the centrifugal tension at 80 feet per second is $\frac{6400}{33}$, or 193 pounds.

The maximum usual tension is 600 pounds in such a rope. Deducting a tenth of this for the slack side tension leaves 540, from which, if 193 be taken, we have left 347 pounds working load. For a total of 600 pounds stress the maximum speed of the rope would be found at about 77 feet per second, but when wear and tear is taken to account, the paying maximum speed will be found even less than this, the true value being dependent upon the cost of ropes and the cost—initial—of the pulleys, etc. It must be noted also that at a high velocity the initial tension requires to be greater, because of the reduced grip due to centrifugal tendency, and this again tends to lower the speed of maximum efficiency.

It is a mistake to suppose that rope gearing absorbs so very much more power than belts or toothed gears. A roped engine may show a greater friction diagram, but the cause is one rather of fly-wheel weight, and the heavy rims used for ropes have been found very effective in promoting steady running, and necessarily add to the friction of an engine. For steady, continuous work the year through and freedom from breakdown and anxiety, the use of large engines and rope gearing can hardly be rivalled by any other system. But armatures ought to have their fly wheels in the same way as they are supplied in direct driving, namely, upon the spindle of the amature.

SPECIAL NICKEL, CHROMIUM AND SILICON STEELS.*

By A. Abraham.

In the first part of his paper the author speaks in a general way of the use of nickel and chromium in the manufacture of steel, but more especially in regard to its application in the manufacture of armor plates. As far back as 1878 the steel works of Holtzer in France made thin plates (four milimeters), containing chromium, for the French navy, while it was only ten years later that the Creusot manufactured for the first time two lots of armor plates made with nickel steel for one of the French ironclads. These plates are supposed to have contained 0.30 per cent. of carbon, 0.5 per cent. manganese and 2.5 per cent. nickel. The results of two plates of that composition, tested on the proving ground, were inferior and showed the steel to be very brittle.

The Creusot works, undaunted by such results, continued in that line and had the satisfaction to establish the supremacy of nickel plates in the now famous international tests that took place at Annapolis in October, 1890. In this test, as is well known, the nickel steel plate furnished by Creusot was found to be superior to an ordinary steel plate manufactured by the same concern and to a compound plate from Cammell & Co., of Sheffield, England.

After these remarkable tests all the large armor-plate makers took up the manufacture of these special nickel plates, and after some further testing it was well established in 1892 that nickel plates, containing chromium in some cases, were superior to all other plates, more especially in regard to resistence to perforation.

In a tabulated form the author submits the chemical analyses

* Abstract from the Annales des Mines by J. B. Nau, reprinted from the "The Iron Age" of Febuary 2, 1897.

and the results of the mechanical tests obtained with a certain number of samples taken from armor plates, of which some contain nickel, others chromium, and still others both nickel and chromium. Without going into any further details of this long table, we may state that the results of the mechanical tests, even with only small differences in the chemical composition, vary greatly in the different steels. These variations are mostly due to the treatment to which the steel is submitted. A very small variation in the temperature of the hardening as well as the annealing operations may in a large measure change the mechanical properties of the metal. The table shows in a very marked degree the high limit of elasticity obtained with some of the steels as compared to their ultimate resistance after tempering and annealing. With an ultimate resistance of about 70 kilograms per square millimeter (99,540 pounds per square inch), ordinary armor plate steel has an elastic limit of only 40 kilograms (56,880 pounds), while steel with 1.5 per cent. of chromium and no nickel has an elastic limit of 50 kilograms (71,100 pounds), and steel with 2 per cent. of nickel and 0.75 per cent. of chromium one of 56 kilograms (79,632 pounds).

The analyses of the steels here quoted, taken from the table, are as follows:

	Carbon.	Silicon.	Manganese.	Chromium.	Nickel.
Ordinary armor-plate steel	0.45	0.20	0.50	.....	.....
Chromium steel	0.46	0.16	0.43	1.52	.....
Nickel and chromium steel	0.31	0.16	0.35	0.75	2.05

Furthermore, the "stricture" ratio of the difference between the original and the reduced area after breaking on one side and the original area on the other side in some cases is higher than 60, even when the ultimate resistance is above 80 kilograms per square millimeter (113,760 pounds). (The stricture is equal to $\frac{a - a^1}{a}$, where a equals original cross section of test bar and a^1 the cross section in the region of the rupture.)

The drop tests for both nickel and chromium steels show little

brittleness but great malleability, even in the cases of steels with an ultimate resistance of 90 kilograms per square millimeter.

Few tests have been made concerning the influence that hardening and annealing have on the qualities of nickel and chromium steel. The author, however, quotes the results of the mechanical tests made with steel obtained from two 10-inch armor plates. The metal contained about 0.40 per cent. of carbon, 0.80 per cent. of chromium and 2.5 per cent. of nickel. The plate had first been forged under a 50 ton hammer, then rolled lengthwise and crosswise. The first plate was afterward annealed at a cherry-red heat, hardened at a temperature of 900 degrees in water at 65 degrees centigrade. This last temperature was maintained as much as possible. After this the plate was again annealed at a temperature of 550 degrees, but the metal at this state being still too hard a second annealing at a temperature of 575 degrees was resorted to. The straightening was done under a hydraulic press at a temperature of 550 degrees. The second plate was hardened in water at 75 degrees without any previous annealing. The hardening was followed by two further annealings, during the last of which the plate was straightened.

A table showing the results of the mechanical tests to which the metal of the two plates was submitted before hardening, between hardening and the first annealing and after the second annealing is published by the author. This table shows that hardening increases the tensile strength of the metal, decreases its elongation, but increases its stricture. Now, the stricture constitutes a very important element in regard to the kind of the local deformations that take place during the test of thin plates. It is due to this high stricture after hardening as well as to a mere tendency to crack that the nickel and chromium steel is so superior to the ordinary carbon steel in the manufacture of armor plates.

Another plate of nickel and chromium steel rolled but not hammered, annealed at a bright cherry red (about 950 degrees) before hardening, then twice hardened again at 950 degrees in water and finally annealed after hardening at a nascent cherry red (about 800 degrees), was submitted to mechanical tests in its natural state and again after it had been submitted to the above

operations. The table published on this test shows that hardening and annealing increase considerably more the elastic limit than the ultimate resistance, and that in spite of a reduction of about 4.5 per cent. in the elongation the stricture is considerably increased.

Where it was desired to obtain a very hard plate, as high as 1.10 per cent. of chromium was added, together with 2.15 per cent. of nickel. Chromium when alone hardens steel but little, but in presence of nickel it makes it possible to obtain a plate which, when tempered at a cherry-red heat and annealed at 550 degrees, had an ultimate resistance of 90 kilograms (127,980 pounds) and an elastic limit of about 80 kilograms (113,760 pounds).

Dead soft steel containing about 1 per cent. of nickel, after having been hardened at a cherry-red heat and annealed at a dark-red temperature, becomes entirely fibrous or has a fine, dull grain. Steel with about 1.5 per cent. of nickel has an ultimate resistance of more than 40 kilograms (56,830 pounds); its stricture is noticeably decreased. Yet the metal, well treated, is not brittle.

THE USE OF NICKEL IN THE MANUFACTURE OF GUN STEEL.

The following analysis of steel was adopted in 1894 by the steel works of Imphy for their gun metal: Carbon, 0.30 to 0.50; silicon, 0.20 to 0.25; sulphur, 0.01; phosphorus, 0.015; manganese, 0.38 to 0.42; nickel, 2 to 2.25, and chromium, —. This metal can be forged without difficulty at a somewhat bright cherry-red heat. After annealing at a dark-red heat test pieces, cut crosswise, gave the following result: Elastic limit, 35 to 38 kilograms (49,770 to 54,036 pounds); ultimate resistance, 55 to 60 kilograms (78,210 to 85,320 pounds), and elongation, 19 to 20 per cent.

Similar test pieces, hardened at a cherry-red heat and annealed in a wood fire with long flame, gave as result an elastic limit of 50 to 52 kilograms (71,100 to 73,944 pounds), an ultimate resistance of 65 to 70 kilograms (92,430 to 99,540 pounds), and an elongation of 16 to 17 per cent. With metal containing

2.5 per cent. of nickel and 0.5 per cent. of chromium about the same results are obtained.

Steel with more than 2.5 per cent of nickel has a tendency to crystalize. Fine crystals in the shape of long, narrow needles form in the heart of the ingot. These crystals will not disappear either by forging, annealing or hardening. Rolling places the crystals lengthwise. Test pieces cut crosswise have crystalline fractures without elongation or stricture. Drop tests are impossible. The author speaks further on of similar results obtained with nickel steel in the United States. He states that in some works steel containing about 3 per cent. of nickel can with the right treatment be made to have a resistance varying between 60 and 95 kilograms per square millimeter (85,320 to 135,090 pounds). With an ultimate resistance of from 75 to 85 kilograms (106,650 to 120,870 pounds), either a great elongation or a high limit of elasticity with high stricture and only little elongation can be obtained.

HIGH NICKEL STEELS.

The author, speaking of this class of steel, quotes the very first tests made with high nickel steels and publishes some tables on the tests made in 1888 by James Riley of Glasgow. These tests were made on a great number of steels, of which the lowest contained 1 per cent. and the highest 49.4 per cent. of nickel. Without entering into any further details we may state here some of the principal conclusions drawn by Mr. Riley from his tests. High nickel steel is easily made in the open hearth; the metal is fluid and homogeneous. Forging and rolling require no particular precautions, except in the case of 25 per cent. nickel steel, which must be heated less than ordinary steel. Nickel increases considerably the elastic limit and the ultimate resistance without much decreasing the elongation. Steel which otherwise would not be very hard, when containing about 10 per cent. of nickel becomes very hard. The presence of nickel between amounts of 10 and 25 per cent. in the steel counteracts the hardening action of carbon and increases the elongation. In one sample of such steel containing 0.82 per cent. of carbon and 25

per cent. of nickel an ultimate resistance of 67 kilograms (95,274 pounds) was obtained with an elongation of nearly 50 per cent. When the nickel reaches 50 per cent. in the steel the metal loses its qualities.

Steel with a high percentage of nickel acquires a beautiful polish. It resists corrosion much better than ordinary steel. It has been noticed that it requires ten times more time to corrode to the same degree a 5 per cent. nickle steel than it would require for ordinary soft steel with 0.18 per cent. carbon, and it requires 15 times more time when, instead of comparing with soft steel, this comparison is made with a steel containing 0.40 per cent. of carbon and 1.60 per cent. of chromium. If, instead of 5 per cent. nickel steel, a 25 per cent. nickel steel is considered, the same ratios will be 87 and 116. These results have been obtained by plunging the test piece in water containing muriatic acid.

Up to 5 per cent. nickel the steel can be easily machined; with more nickel this becomes more difficult. Steel with 1 per cent. nickel welds well; with more nickel this quality decreases.

At the Cockerill Works at Seraing, Belgium, a series of tests were undertaken in 1894 for the purpose of obtaining a steel with a very high limit of elasticity, great ductility and malleability. The best results were obtained with a ferro-nickel, or compound of nearly pure iron and nickel. The engineer in charge of the tests established a comparison between this metal and an open-hearth carbon steel which as far as possible should give the same hardness. The analyses of the two metals follow:

	Ferro-nickel.	Carbon steel.
Carbon	0.06	0.55
Silicon	0.01	0.20
Sulphur	0.02	0.03
Phosphorus	0.016	0.047
Maganese	0.35	0.70
Nickel	7.50	...

Some of the results of the mechanical tests to which the two steels were subjected are as follows:

	Limit of elasticity in kg. per sq. mm.		Resistance per sq. mm. in kg.		Elongation.		Contraction.	
	Ferro-nickel.	Carbon steel.	Ferro-nickel.	Steel.	Ferro-nickel.	Steel.	Ferro-nickel.	Steel.
In their natural state.....	40.5	51.6	54	86	24.3	12.1	60.4	24.4
Hardened in water at 900 degrees.....	107	53.2	125	73.8	10.2	2.2	50.5	0.9
Hardened in water at 900 degrees; annealed at 500 degrees.....	82.3	80.2	82.7	102.9	12.5	7.7	61.2	27.3
Hardened in oil.....	97.3	71.6	99.6	93.4	9.3	1.8	42.3	4.7
Hardened in oil, annealed at 500 degrees..	81	78.8	84	106	12.2	9.8	52.5	27.3

The table shows in what respect ferro-nickel is superior to carbon steel. But it must also be stated that when hardened the above ferro-nickel retains a silky fracture, similar to the fracture of the non-hardened material, while the fracture of the hardened carbon steel is dry and granular. Blow tests break at once the hardened carbon-steel test bar, but simply bend without cracking the hardened ferro-nickel test bar. Further tests made on tests bars of ferro-nickel of the above composition and on homogeneous iron of the same composition but without nickel, have shown that when submitted to transverse action or bending the elastic limit was found to be 27.9 kilograms per square millimeter (38,874 pounds) in the case of homogeneous iron, and 50.9 kilograms (72,380 pounds) in the case of ferro-nickel. Leaving the price out of consideration, ferro-nickel is superior to homogeneous iron in every respect.

Some French steel works have made a series of methodical researches on different nickel steels. The most complete researches seem to have been made by the Saint Jacques Steel Works at Montluçon. The results obtained by the mechanical tests of these steels permit a classification of the metal into three different groups:

1. Steel containing 2 to 5 per cent. of nickel. Their resist-

ance increases with the percentage of nickel, especially when the carbon content is low. When carbon reaches 0.50 per cent. or more, the presence of nickel has little influence. Steel of this class forges and rolls well. When hardened, the ratio of elastic limit to ultimate resistance becomes very great.

2. Steel containing from 10 to 20 per cent. of nickel. The resistance increases again with the amount of nickel. An addition of 0.10 per cent. of carbon increases the ultimate resistance from 30 to 65 kilograms (42,660 to 92,430 pounds). Such steel containing 20 per cent. nickel has a resistance of 110 kilograms (156,420 pounds). If at the same time the carbon increases up to a certain limit, a resistance of more than 200 kilograms (284,400 pounds) can be obtained. The upper carbon content at which the resistance of a 10 per cent. nickel steel begins to decrease again is 0.50 per cent.

Steels of this second class do not harden much, and do not harden at all when their carbon content is higher than 0.10 per cent. Twenty per cent. nickel steel never hardens. All are very brittle. They forge and roll well, but when containing more than 0.10 per cent. of carbon they cannot be machined.

3. Steel containing from 20 to 25 per cent. of nickel. Their elastic limit as well as ultimate resistance is low. They have great elongation and are nearly free from brittleness. When forged at a low temperature without annealing their elastic limit increases notably and has reached 55 kilograms per square millimeter (78,210 pounds), with an ultimate resistance of 80 kilograms (113,760 pounds), and an elongation of 25 per cent.

With carbon content of less than 1 per cent. the steel can easily be forged and rolled. Steel with 1 per cent. of carbon can be forged between 500 and and 1,000 degress with light blows. Machining is difficult but not impossible. From these tests it results that only the steels of the first and third classes can be used for practical purposes, the steels of the second class being too brittle and too difficult to machine.

NICKEL-CHROMIUM STEELS.

In his second chapter the author analyzes the qualities of steels containing both nickel and chromium. This class of steel

has been thoroughly tested by the steel works of Imphy in France. In 1894 these works had received an order for two kinds of nickel steel or ferro-nickel, one to be very soft, not susceptible to being hardened, but with a very high elongation just before breaking; the other to be very hard, susceptible to be worked with a tool and have the highest possible elastic limit. Without entering into any of the details submitted by the the author, we reproduce here the analyses of some of the typical steels that were especially manufactured and thoroughly tested by the steel works before satisfactory results were obtained.

	N. 1.	N. C. 1.	N. 2.	N. C. 2.	N. W. 1.	N. C. 3.	N. C. 4.
Carbon.....	0.05	0.412	0.610	0.455	0.566	0 535	0.760
Silicon.....	0.035	0.221	0.326	0.385	0.232	0.527	0.469
Sulphur	0.030	.....	0.035	0.034	0.029	.....	.....
Phosphorus.....	0.048	.....	0.010	0.029	0.120	0.011	0.013
Manganese	0.085	0.288	0.245	0.410	0.500	0.324	0.360
Nickel.....	25.88	5.65	24.72	24.150	24.320	24.86	24.960
Chromium.....	.....	1.03	.....	0.413	.....	1.420	2.88
Tungsten	.....	.....	.....	.....	2.05	.....	.....

Steel N. 1 had in the ingot all the characteristics of a 25 per cent. nickel steel. Numerous crystals in the shape of fine needles started normally from the surface toward the inside of the ingot. These needles cut each other on the two diagonals of the square cross section. The center of the ingot is composed of small crystals placed without order. In regard to some results of the mechanical tests, we will briefly state that steel N. 1 was very difficult to work; it could be cut with a tool made of soft steel. Its ultimate resistance was 90 kilograms (127,980 pounds), its elongation 4 per cent. It gave no satisfaction. Steel N. C. 1, which was intended to have a high elastic limit, could not be practically utilized on account of its extreme hardness. The annealed metal had an ultimate resistance of 70 kilograms (99,540 pounds), the hardened metal of 135 kilograms (191,970 pounds).

Metal N. 2 was intended to take the place of N. 1 with a higher percentage of carbon and was expected to give better results in regard to hardness. While there was some slight improvement in that respect it was far from sufficient. Since this sample showed that carbon alone would not produce the desired results, it was

deemed advisable to try additions of other metals, and sample N. C. 2 was obtained with an addition of chromium. This metal forged well, especially when forging was begun at a low temperature. It rolled well. Its ultimate resistance was 77 kilograms (109,494 pounds), with 52 per cent. of elongation. One test bar of it was annealed and elongated 30 millimeters. This special test bar was annealed ten times in succession, and the aggregate elongations are claimed to have been 342 millimeters, or 242 per cent. A drop test could be repeated 15 times on the same bar, the bar being turned each time; it broke only after the fifteenth drop. This metal is remarkably tenacious, and even after having been deeply cut it was broken only after many difficulties.

With all these qualities the steel was difficult to work and failed to have the desired hardness. Tungsten was then tried in sample N. W. 1. This metal forged well. A rolled bar in its natural state had an ultimate resistance of 86.7 kilograms (123,287 pounds), with 41 per cent. elongation. Annealed, its ultimate resistance was 78.5 kilograms (111,627 pounds), with 44.5 per cent. elongation. The metal does not harden, can be worked a little better than N. C. 2, but it failed again in the right hardness. Tungsten having failed, chromium was again tried, but this time in larger amounts. See sample N. C. 3. This metal forges well. It is more easily worked than N. C. 2, and its hardness has considerably improved. While not yet entirely satisfactory it showed conclusively that by the use of chromium in the right proportions the best results would be obtained. The metal N. C. 4, with about twice as much chromium as in the previous sample, was then made. This metal forges well and has sufficient hardness. It works well cold.

The hardening operation has on the metal the same effect as annealing. In its natural state its ultimate resistance is 104 kilograms (147,888 pounds), with 19 per cent. of elongation. Annealed at a cherry red it withstands 99.5 kilograms (141,489 pounds), with 29 per cent. elongation. The elastic limit was observed to be 60 kilograms (85,320 pounds). On another sample the elastic limit was found to be 73 kilograms (103,806 pounds), with an ultimate resistance of 95 kilograms (135,090

pounds), and an elongation of 29.8 per cent. Some other compositions of metals were tried. Some contained more chromium, others contained, in variable quantities, tungsten, nickel and chromium. In still other samples the amount of manganese was variously increased with the suppression of chromium. The results in all the cases, however, were inferior to what had been obtained with the metal N. C. 4.

After having satisfied themselves by numerous tests that a composition similar to the one of the metal N. C. 4 was the best for their purpose, the Imphy Steel Works began to manufacture the metal in large quantities in the open-hearth furnace. We reproduce here the details of the very first charge of this kind in the open-hearth furnace as typical of all other heats. The bulk of the nickel, of 1,100 kilograms was introduced in the furnace with the charge. Further 300 kilograms were added after the fusion of the charge. At the end of the operation 350 kilograms of ferrochromium were introduced, and finally, a few moments later, the ferromanganese was added for deoxidizing and recarburating purposes. The whole heat lasted 6¼ hours and was made very successfully. Fifty-seven hundred kilograms of finished metal were obtained from a charge of 5,910 kilograms. This constitutes a loss of only 4.4 per cent. The metal contained 20.06 per cent. of nickel and 3.16 per cent. of chromium.

A test piece cut lengthwise from a rolled bar had a resistance of 97 kilograms (137,934 pounds), with 34 per cent. of elongation. Two test pieces cut crosswise from a rolled bar were also tested. The first one, in its natural state, had an ultimate resistance of 80 kilograms (113,760 pounds), with 28.4 per cent. elongation; elastic limit, 44.2 kilograms. The second test bar, three times hardened, had an ultimate resistance of 77 kilograms (109,494 pounds), an elongation of 42.6 kilograms (60,577 pounds) and an elastic limit of 36.6 kilograms. Numerous tests were made with the metal of this heat. All these tests are fully reported on by the author. We will only state here that the metal forges well, but is hard enough not to be much influenced by the hammer when its temperature falls to cherry red. Small superficial cracks appear during the forging process at each

heating, the chiseling of which is very difficult, on account of the chisels wearing out quickly. When heated too much or unequally the metal becomes brittle.

From one ingot, weighing 1,600 kilograms, a gun tube was made. Its forging was easy, but in the lathe it exposed numerous little veins all placed longitudinally on one side of the tube. One test bar of this metal taken from the end of the tube after nine successive reforgings had a resistance of only 69 kilograms (98,118 pounds), with 21.5 per cent. elongation. The fracture looked like rotten wood. This phenomenon was probably due to crystallization that remained in the metal, which had probably been forged at too low a temperature in order to avoid cracks. The metal from the same test bar being three times in succession plunged in water at a cherry-red heat, the crystallization disappeared, the ultimate resistance rose to 73 kilograms (103,806 pounds), with 50 per cent. of elongation and a stricture of 54. The fracture of this bar was silky.

Bending tests of a peculiar kind were resorted to. The machine to make these tests is a lathe so arranged that a square test bar fastened with one end normally to the end plateau of the lathe will revolve around its center line at the end fastened to the plateau of the lathe. The other end of the bar is not fastened, but is bent upward and kept there by means of a transverse iron bar, laid higher than the axis of the lathe and normally to this axis. When the lathe revolves, the end of the test bar fastened to the lathe will revolve with it, while the free end of the bar, lifted up, will also revolve around its own eccentric axis, but not around the axis of the lathe. The result will be a continuous bending of the test piece successively on each of its faces in the section where it is fastened to the machine, and finally the breaking of the bar in this section.

A bar of the above metal in its natural state was submitted to 42,000 revolutions of the lathe without breaking. Ordinary steel of about the same resistance and annealed at a cherry-red heat broke after 13,273 revolutions.

The same metal was also extensively tested in castings, but the results not being satisfactory this practice was abandoned.

We will state only that from the many casting tests made the conclusion is arrived at that the peculiar crystallization of which we have already spoken cannot be avoided and is considered as one of the great causes of failure. Annealing was tried to improve the castings, but while some improvement was noticed partial crystallization still happened. The operation of hardening constituted a very great improvement, without, however, doing away entirely with crystallization. Hardening, however, is a dangerous operation to be applied to castings.

During the numerous tests to which this steel, N. C. 4, was further submitted, and which are fully reported on by the author, practical points in regard to forging and machining have been noticed. The temperature at which the metal can be worked must not be higher than very bright cherry red nor lower than cherry red. We quote here that a heavy ingot, weighing 3,588 kilograms, which was transformed into a rudder for one of the vessels belonging to the French navy, was put in the heating furnace at 5 o'clock in the morning while the heating furnace was at a dark-red temperature. For two hours the ingot was left to heat up slowly until it reached the temperatare of the furnace. The heat of the furnace was then slowly pushed until, at 2 o'clock in the afternoon, a very bright cherry red was obtained. The piece was then forged step by step. Some parts of the rudder required as many as twenty-three successive heats before their final shape was obtained. During these operations at different times superficial cracks opened either on one or several faces or in the corners. Good care was taken to remove these cracks before proceeding any further. At one time, to remove cracks that had formed in one of the corners, two complete heats were required. Outside of these cracks no serious defects were noticed. The operation of forging such metal, on account of the narrow limits within which this operation can be done, is necessarily very slow.

The tools that were used in the machinery are slow working. They are mostly chromium or tungsten tools. One tool, containing 0.60 per cent. of chromium and 2 per cent. of tungsten, gave satisfactory results when hardened at a dark-red heat.

Another tool, with 2.5 per cent. of chromium and 9 per cent. of tungsten, required no hardening. This tool also contained 2.16 per cent. of manganese, which made it possible to forge it easily. The one tool that gave the greatest satisfaction and which can be forged, hardened and tempered easily, contained 6.5 per cent. of tungsten and 0.8 per cent. of chromium.

Tables showing the itemized cost price of one rudder shaft made of nickel chromium steel and a cost price of a rudder shaft made of soft steel were submitted. They show that the first rudder cost 3.51 times more than the last one. In these cost prices labor enters for about one-quarter and steel and fuel for three-quarters in the case of the soft-steel rudder shaft. In the case of the nickel-chromium steel rudder shaft labor enters for one-eighth and steel and fuel for seven-eighths. In these prices the shafts are considered of the same size. But a nickel-chromium steel shaft, on account of its greater strength, may be 23 per cent. less in diameter than a soft-steel shaft, or 41 per cent. in volume. Under these conditions the price of the nickel-chromium steel shaft is only twice as high as the one of soft steel.

EARLY STEAMBOATS.

By Chief Engineer Geo. W. Baird, U. S. Navy.

The very interesting chapter by Mr. Haswell in the last issue of the Journal, has led me to submit the following notes on the earliest steamboats that came to my notice.

When a small boy (1855), I visited Baltimore with my father, and while there he pointed out a steamboat that he said was about thirty years old. My recollection is that her name was *Kentucky*. She was built by Watchman and Bratt, at Baltimore, where my father had been foreman. She had a square engine, with a single cylinder, about 30 inches diameter of bore, and about 7 feet stroke of piston. The cylinder was cast in two pieces, because they had no means of making so large a cylinder in one piece. Each half was bored out separately; the flanges were chipped and filed by hand, then bolted together; and then the cylinder was bored out again. It seemed they had no lathe that could face the flanges, and the hand job was pointed to in great triumph; it was regarded as the very acme of the art of chipping, filing and fitting. The vessel had originally a wooden shaft; later, a cast-iron hollow shaft, and, finally, a wrought-iron solid shaft.

Another very successful boat, built at Baltimore about 1830 by the original "Charlie" Reeder, was the *Columbia*. She had a pair of overhead beam engines, about 40-inch cylinders, and about 10 feet stroke of pistons, and was "very fast;" but she shook so badly that they removed one engine and one boiler. Her boilers were copper, and were used up to 1855. She had a new and larger engine put in during '58. She made weekly trips between Washington and Baltimore up to 1861, when she was withdrawn in consequence of the war.

My recollection of these vessels is that their connecting rods, links, air-pump rods, &c., were all polished, and the stub

ends handsomely finished. They had single poppet valves, and it required a powerful man to handle their starting bars. The *Columbia's* cut-off was a butterfly valve in the steam pipe. For this the Sickles cut-off was substituted early in the fifties; its details were not well worked out; it tripped only when the valve was lifting, so could not cut off beyond half stroke. The saving of fuel due to the improved cut-off was considerable, but the owners refused to pay what they had agreed (a percentage of the saving), which resulted in that famous lawsuit in which Mr. Dickerson won the unique distinction of becoming an engineer by the use of words instead of acts.

U. S. SHIP *UNION*.—The engines of the *Union* were designed by Mr. William Ellis, whom I knew well, who was master mechanic at the Washington Navy Yard, and who was one of the best engineers of his day. The wheels were invented and patented by Lieutenant W. W. Hunter, who spent much of his private fortune on their development. The hull was built and shaped to accommodate the engines. It had two beams, on deck, 33 feet 6 inches, and at the wheels, several feet below the water line, the beam was reduced by a reverse curve to 26 feet; the bottom was flat and the turn of the bilge was sharp.

As a ship she was possessed of many bad qualities; slow under steam and slow under sail; could not be made to "lay to" nor keep the wind with head sails set and hauled flat aft; the center of gravity of the load line and transverse area were so far aft as to make her unmanageable in a sea way.

The engines were two in number, were non-condensing, and independent of each other. One engine turned each wheel. The wheels were similar to paddle wheels, but were mounted on vertical axes, working in drums inside the hull, with the width of a paddle extending beyond the side. Mr. Hunter saw the advantage of getting the propeller under water, that it might be protected from the enemies' shot. Following are some of the principal dimensions.

Diameter of steam cylinders, inches	28.
Stroke of pistons, feet	4.
Nominal horse power	159.
External diameter of wheels, feet	14.

Vertical length of paddles, feet	4.
Breadth of paddles, inches	10.
Number of paddles in each wheel	20.
Number of boilers	3.
Type of boilers	Cylindrical, tubular.
Total area of grate surface, square feet	159.
Total area of heating surface, square feet	2,800.
Length of each boiler, feet	18.
Diameter of boilers, feet and inches	6–5

COST.

Of hull	$87,864.00
Of engines	53,187.00
Of boilers	13,754.00
Of extras and alterations	17,670.00
Total original cost	172,477.00

PERFORMANCE UNDER STEAM IN DECEMBER, 1844.

Boiler pressure, pounds per square inch	80.
Mean number of revolutions per minute	26.
Cut-off, from commencement of stroke, inches	24
Mean number of pounds of coal consumed per hour	2,200.
Indicated horse power developed by the engines	300.
Mean speed in nautical miles per hour	5.
Pounds of (Cumberland) coal per I.H.P. per hour	7·333
Percentage of loss in propelling instrument	54.

Lieutenant Hunter commanded the *Union* when she was commissioned, but she never left the coast. Larger boilers were subsequently put in the vessel, and some alterations were made to the wheels. A pressure of from 70 to 100 pounds was carried in the new boilers, but they were soon ruined by scale. In 1846 she was again "repaired" and new engines, 40 inches in diameter and 4 feet stroke of piston, put in. These were condensing engines; "new arches" were put in the boilers and the number of paddles in the wheels was reduced by one-half. On trial she made seven knots.

In fairness to Mr. Ellis, it is proper to say that he designed the original non-condensing engines under orders, after urging the advantages of a condensing engine. The original engine was designed and built under the administration of the Board of Commissioners, but the new one was built after the bureau system was inaugurated. The machinery of the *Union* was condemned and taken out at Philadelphia in 1848.

MALLEABLE CAST IRON.

By Erastus C. Wheeler.

[From "The Iron Age," February 16, 1899.]

The manufacture of malleable cast iron at the present day is accompanied with a vast quantity of what might rightly be called contradictory knowledge. This has been occasioned in no small degree by the close attention given each local condition, to the exclusion of that confidence in the art which has so beneficially encouraged its former rival, gray iron. There has been, and is still prevalent in many quarters, a decidedly sensitive feeling that malleable iron founding is somewhat of a metallurgical secret. And this fact may in a measure account for the lack of literature published bearing upon the subject. This industry, comparatively speaking, is still in its infancy. From its humble and praiseworthy efforts in the early thirties to make itself a known factor in the arts, it has developed so rapidly in later years that its product is now a recognized and highly essential article of commerce. It has crept slowly, and with many a hard-fought battle to its credit, into the very strongholds of gray iron, and, once there, has never been overthrown.

As in the modern evolution, it is the strong against the weak, and this competition will continue until it has a dominating position in the metal-casting world. When that point has been reached it will be the turning of its great success, for then, and not until then, will the moment be ripe for the advent of its successor. Already the commercial world has heard a faint whisper as to what the aspirant will be, and has recognized with some little financial encouragement several attempts at its production. But the day for a metal which shall be malleable without the long annealing operation, and which will present a surface comparing favorably with the material of to-day, is many years hence, and present plants have nothing to fear in that direction. The

year just closed has marked the highest tonnage in its history. Its adaptability to an almost unlimited variety of work makes it at once a most necessary article of construction. It has almost entirely superseded gray iron in freight-car building, and its entrance into the great field of agricultural supplies will be, as its former trials, a success. In the carriage and saddlery-hardware branches the malleable casting presents an indisputable article of superiority over the hand-forged article of twenty years ago. The uniformity and smoothness of its surface together with the homogeneous nature of the metal insure its great demand in the commercial world.

In no other branch of the metal world has the tonnage increased so markedly compared with a former year as the malleable casting. Recent and reliable figures place the tonnage for 1898 as 50 per cent., increase over 1897. The enlargement of present plants, the building of new works and the contemplated erections for the early season of 1899 are due indications of the great success of this most staple article. A better feeling has developed during the past few years (and this is best proven by the large attendance of malleable makers in conventions) toward advancement of the art, without those jealous restrictions of past years. There is no secret about it, and one maker may be more successful through executive ability and care in details, rather than in marked superiority of finished article.

The entrance of the chemist has been productive of larger benefits than in the gray-iron industry. The careful selection of raw material for mixture, and thoughtful analyses presented, have all tended toward an advancement which has been unprecedented in the casting art. The promptness of blast-furnace management to go on malleable burdens and meet the requirements of specifications, which are now closely confined, but which will broaden, has been one of the most encouraging features of all.

The greatest barrier was the prejudice of people (used to gray-iron weight) to the lighter and stronger article. But these battles have been won, and the malleable casting is no longer a matter of doubt. It is the purpose of this article to deal with the effects, for good and bad, of the impurities found in pig iron.

They are taken in the order in which, according to latest practice, their importance is placed, and beginning thus we have silicon.

THE INFUENCE OF SILICON.

Of all the metalloids contained in pig iron, this is probably the one upon which the greatest dependence is placed. It is conceded that silicon promotes the separation of graphitic carbon, and in the malleable casting these two metalloids are destined to assume important parts. It might be well to trace the formation of silicon back to the blast furnace, and endeavor to comprehend a few of the chemical phenomena incident to its production. In all the material charged into stack, fuel, limestone and ores, silica is present in varying quantities. When the charge has passed the fusion zone the reduction is complete and the chemical reaction from silica to silicon has taken place. The amount of silicon and carbon contained in pig iron will depend in a great measure upon the good working of the furnace. If the latter is operating very hot a high-silicon product will result, but if the furnace, through atmospheric conditions or other wise, is cold the low-silicon white iron is made. Why the furnace conditions govern the amount of silicon present is a question rather of blast-furnace practice than of malleable founding, but there is one patent fact, which should be clear in every foundryman's mind—namely, that the term silicon means " heat."

In calculating mixtures for the casting of light work the percentage of silicon is usually kept high, and the amounts of other alloys (with the possible exception of phosphorus) do not differ materially from mixtures made for heavy work. A metal is desired which will retain its heat for a considerable period, and the resource for it is higher silicon. Gray iron will contain its heat much longer than air-furnace metal, pour smaller work, and yet its appearance does dot denote this propensity. It will be argued the carbon exerts great influence in this matter, and there is, no doubt, weighty truth in it, but the main and lasting factor is silicon. Gray iron is hot of its contained latent energies, while malleable metal is hot mainly through the induced heat of the furnace, together with its lesser silicon. Burn the silicon and carbon com-

pletely out, and a metal resembling steel will result, which cannot be poured with success in green sand molds, but which requires a hard surface for metal to run over. It is poured under pressure, because its life has been completely eliminated, through the loss of its alloys. How often has malleable metal appeared hot and yet has misrun the patterns? Silicon from its origin in the ores as silica, through the blast furnace, into pig metal, and the reduction of the latter in reverberatory furnace, as malleable, is the synonym for heat units. Without its dominating presence in mixture iron will not remain hot and liquid to the successful casting of light work. It is a great necessity. Silicon in conjunction with manganese affects the shrinkage of metal materially.

The term shrinkage must not be misconstrued as a reduction in values or weights, but the contraction incident to cooling. If the annealing process were carried through without its attendant loss of silicon and carbon, castings would be of the same dimensions as when cast, the expansion having equaled the contraction. The higher the percentage of silicon the longer the metal will remain hot after pouring, and with a reduced shrinkage, the lower silicon, the more rapid cooling will take place, with greater contraction. As regards the heat of malleable metal, there are many times when iron is not only too hot of itself, but with the induced heat of blast will, after pouring, present the elements of segregation to contend with. This latter difficulty is caused by the internal pressure generated by the center being the last part of casting to cool, drawing the already cold exterior inward. When a chill is applied to these affected spots there is another feature presented—namely, internal shrinkage—and is caused through the surface being chilled, and as exterior cools the strains generated and the resistance met with cause the iron to strain and pull apart, leaving the familiar shrinkage spots in centers. It has been general practice until a few years ago to place heavy risers upon all large castings, in order to "feed" the same properly during the period of cooling, but this has been discontinued, owing to metal segregating under heads, leaving a hole visible upon the surface. These

defects have been overcome through the agency of another metalloid, manganese, which will be described later on.

Malleable iron has not as yet reached that point where it could be compared with gray iron, regarding the uniformity and homogeneity of fracture. Perhaps this may be considered a metallurgical impossibility, but yet it is hoped for. There is a very reliable test for the amounts of silicon required in mixture, and careful manufacturers place great confidence in same. A test bar exactly 12 inches long and $\frac{1}{2}$ inch thick is cast from every heat, and a micrometer reading is made off same. If the shrinkage is found to be greater than that allowed in patterns the silicon has been too low; if the contraction has been less the percentage of silicon was high, and it then resolves itself into a question for manipulation to adjust this, the idea all through being that a high-silicon liquid iron will cool slower, with less contraction, than a low-silicon, duller iron, with its greater shrinkage.

The presence of a large percentage of silicon will assert itself when after annealing the fracture will show a wide, white edge and is brittle. The non-removal of silicon in appreciable amounts may be due to the fact that it is not acted upon by the carbon dioxide during the process of decarbonization. Silicon grades the pig iron, being, as before stated, a promoter of graphitic carbon. Foundrymen are looking forward with interest toward a more universal method of grading. A great many malleable concerns who do not employ chemists, but who accept furnace analyses, and who in a degree regulate their mixtures with regard to the appearance of the pig, are often misled by the appearance of graphitic carbon. In one grade, pigs showing the large open crystals and some the close grain will be found, yet in silicon these may vary appreciably. The open grain will be the lower silicon and higher carbon, the closer grain the higher silicon with less carbon.

If the grading were always accepted the open fracture would have been called the higher silicon. These two fractures are occasioned by the slightly different casting manipulation at blast furnace. The amount of silicon in mixture for light and heavy

work will, of course, be governed by purely local practice, and no general rule can be laid down for same, as no two furnaces work alike. What would be a general average places the percentage for light work from 0.80 to 1.30, and heavy work from 0.65 to 0.95. In air-furnace practice there often occurs a condition when iron is hot enough to pour, and yet great difficulty is experienced in combining carbon. The very general opinion would be that the iron used is too soft, too high in silicon, and a change is made for lower percentages of same. It may be argued that the higher silicon prevents the combination of carbon in the bath, and yet, if that heat were brought up slower and skimmed earlier, the carbon would have combined readily, and at the proper moment would have been ready to pour, showing distinctly a heat condition rather than an improper mixture. All these annoying problems can be met and remedied by judicious experiment and metallurgical knowledge of a chemist, who should be thoroughly competent to diagnose each phenomenon and advance reliable theories. A great many of the most successful malleable foundries are conducting their business without the aid of a laboratory, yet it is a source of great satisfaction to those who employ chemists to really know why existing defects are possible, and that suggestions may be made for guarding against their repetition.

In preparing a mixture for the air furnace the nature and general dimensions of patterns to be cast are the first considerations. In the large foundries, where the castings are heavy, the pig iron selected for the furnace is chosen with reference to its low silicon and total carbon. The grading of iron will serve as a guide in this particular, a mixture averaging about No. 3½ producing a very satisfactory working in the furnace. An excess of silicon must be avoided, in all cases, because it will produce an inferior brittle article of high tensile strength and no appreciable elongation. There should be a clear understanding in this matter, that while the presence of silicon is a necessity in the melting furnace it is a hindrance to good product after the annealing process. There should be a total loss of at least 40 per cent. silicon from the original mixture to the finished material. Some will be lost

in melting and the balance during annealing. In the following tables this fact will be found clearly demonstrated, the test being taken from regular heats. Where there has been a decided loss in silicon the percentage of elongation has been good, and with a uniform tensile strain:

No.	Tensile.	Elongation.	Silicon.		
			Mixture.	*Soft.*	*Per cent. loss.*
1	46,800	7.32	0.88	0.52	41
2	45,600	8.22	0.80	0.40	50
3	45,000	4.72	0.76	0.45	41
4	43,610	5.33	0.79	0.52	34
5	46,600	5.83	0.73	0.48	34
6	45,600	4.50	0.80	0.40	50

In the following heats the percentage of silicon excluded has been low, and we still find high tensile strength with a small percentage of elongation, and consequently a much stiffer iron:

No.	Tensile.	Elongation.	Silicon.		
			Mixture.	*Soft.*	*Per cent. loss.*
1	45,600	2.25	1.09	0.90	18
2	42,500	2.13	0.77	0.66	14
3	34,900	2.33	0.79	0.68	14
4	37,500	1.83	0.76	0.73	4
5	35,000	1.83	0.79	0.68	14
6	37,400	3.12	0.77	0.59	23

In all these tests the percentages of the other alloys have remained practically constant. Sulphur has averaged 0.043, phosphorus 0.124, and manganese 0.58. If the result of thoughtful research and careful study is to be accepted as conclusive, it would prove the theory that a too-high silicon will not be conducive to good malleable iron. There could be several good reasons advanced in explanation of the fact why the silicon is eliminated in the one instance and remains practically constant in the other. A faulty annealing is one, and an improper combination of silicon and manganese another. Silicon and carbon, working in certain ratios with each other, will not be effectually eliminated by the weak decarbonization of a slow and cold-working furnace. The whole theory of the malleable process is to decarbonize the metal through the aid of an oxidizing reagent, and this is brought about by the use of prepared packing in some

instances, or any substance which has an affinity for carbon under heat. The lower the percentage of carbon and silicon in any metal known to the metallurgist the softer and more malleable it will be; the higher these elements the more brittle it will become. This fact is very prominent in the manufacture of steels.

Malleable cast iron is, therefore, the direct result of decarbonizing cast iron by means of a sesquioxide which will impart a portion of its oxygen to the carbon in the metal at an annealing heat, producing CO, burning the carbon.

THE INFLUENCE OF SULPHUR.

Of all the metalloids found in the composition of pig iron used for malleable purposes, sulphur probably exerts the most negative influences. It is only dependent upon heat conditions in the blast furnace for its existence in pig iron, and when the furnace is working excessively hot there is hardly a trace found. In the case of coke irons, the fuel used has a direct bearing upon its presence. It has a very serious effect upon the regular malleable casting and must, of all the impurities, be most avoided. There is, however, a grade of semi-steel upon the market at present, called McHaffie, which up to a certain point is nothing more than malleable, but which requires a high percentage of sulphur in its production.

This excess sulphur produces a very high combining carbon point, making it possible to pour castings with a diameter of 24 inches perfectly clear. After the annealing, which requires about eight days, the metal presents an entirely different appearance from ordinary malleable, the fracture showing (when the conditions have been favorable throughout process) a crystalline surface, closely resembling an open-hearth steel casting. The sulphur is added to mixture in the form of a sulphide of iron, and about two pounds per ton produces the metal described above. This metal is used with great success in castings requiring a wearing surface with no great elongation or reduction of area in physical tests. The whole idea of the process is to combine the carbon to a point not possible in the malleable casting. In the manufacture of coke iron in the blast furnace, we have in the

fuel used a high percentage of sulphur, and while the furnace is working hot there is no difficulty experienced in eliminating it, through the high volatilization, and also through the slag. But with the changing conditions of heat, the furnace working cold, we find the iron absorbing sulphur in large quantities. Thus in a No. 1 iron sulphur is at a minimum, and in a No. 6 at a maximum. In charcoal irons this feature does not present itself, as the fuel used is very low in sulphur, and a No. 1 or No. 6 varies but slightly in this particular.

We fail to observe any beneficial results arising from the presence of sulphur, and the lower the percentage of it in malleable the more satisfactory will be the product. If, like in the McHaffie process, sulphur could be added in the furnace and carbon combined higher and then volatilized in annealing ovens, we could derive some benefit from it. But with the existing methods of producing and handling malleable cast iron, there is no good excuse for its presence. Sulphur enters readily into combination with the iron, but never, like the other metalloids, loses its individuality (so to speak). It has an all-pervading, permeating tendency to dominate the metal to the serious detriment of its good quality. It destroys early in the process the clinging qualities of the molecules, and high-sulphur hard iron will break very readily. No better example of this can be found than when breaking off gates, particularly if they are heavy, while with low sulphur we meet with some degree of resistance in this particular. In calculating percentages for mixtures it has always been found good practice to use irons varying completely in chemical analysis, for the benefit of obtaining good averages. In this connection it might prove interesting to note the fact that a great quantity of high-sulphur coke iron, made at furnaces during a period of cold working, is thoroughly applicable to good malleable, if used with judgment. We have here an iron low in silicon, high in combined carbon, and with what appears an excess of sulphur. If sulphur averages about 0.75, and is used with irons of about 0.02, we would have another iron to choose from, instead of resorting to the higher priced

grades. As many furnaces recharge this material, a selling price considerably under market quotations could be obtained.

The writer has used many hundred tons of this iron, and when sulphur was kept within 0.045 in the initial charge experienced no trouble from it. With 0.045 in sulphur the limit of safety has been reached. Above that percentage there is danger. That fact will assert itself without fail in the annealed casting. The tendency of high sulphur is to produce "shortness." When making Bessemer steel, after an ingot has been reheated and annealed in the soaking pit, and is introduced into the rolls, and there falls apart like cake, there is but one verdict, "red short," viz: high sulphur, there being absolutely no life in it, and the presence of this alloy has destroyed its tenacity. So with malleable. While we may be able to secure a reasonably high tensile strain, yet the elongation is nothing, and the iron has a short, sharp break. The presence of an excess of sulphur in annealed castings may be detected by the appearance of fracture, coupled with surface indications. On the surface will be found many slight flaws. Taking a draw bar, for example, on its barrel will be found small, and what are apparently shrinkage cracks, extending inward about $\frac{3}{8}$ to $\frac{1}{2}$ inch. The fracture, too, will show a crystalline break, often mistaken for cleavage or underannealing. Both of these mentioned defects will be overcome by the reduction of the sulphur in the mixtures. In offering malleable castings to the commercial users an article possessing ductility, and not high tensile strength, is what specifications should call for. In the case of railroad castings, the softer the product the better it will withstand the sudden sharp strains incident to car service.

In this connection it might be well to approach the physical requirements of the malleable cast iron coupler. It should be "soft," not over 42,000 pounds tensile strength, and with an elongation of at least 8 per cent. in 6 inches. When the tensile strength runs higher we find, after a severe coupling has been attempted, the head of coupler upon the track, instead of attached to the barrel. Malleable iron is a refined cast iron, and in this one instance must not be compared with open-hearth steel, for the claims thus made are not reliable. The relation of

sulphur to the breaking strain is very prominent indeed, and must not be overlooked in any instance. In a lot of 100 malleable couplers returned to a concern during the past year, 80 were found to have been cast in one week, and in every case the head was broken off short at the barrel. The percentage of sulphur in these castings averaged 0.095, and the iron used was a high coke, carrying as per analysis furnished, 0.065 sulphur. If the melter had been better acquainted with blast-furnace working he would have at once questioned that analysis as improbable.

The chemical action of sulphur in the anneal is not as clear as we would desire, but from the fact of its combining the carbon higher the anneal should be shortened perceptibly. It is not at all beyond the range of possibilities that in the coming decade we will have a basic lining brick used in the air furnaces which will eliminate both sulphur and phosphorus as effectually as is now done in the basic Bessemer and Siemens-Martin furnaces. Necessity will advance this process at the proper moment, and it will throw open a wonderful field for iron now debarred to the producers of malleable. At present the sellers of pig metal for use in malleable shops find themselves restricted to rather narrow margins on specifications. Years ago the same conditions prevailed in relation to iron for use in the open-hearth furnaces, owing to the rigidity of government and other specifications, and with this necessity came the dolomite lining for vessels and furnaces. It is not that the elimination of sulphur in the ores is an impossibility; in fact, this is a highly accomplished modern operation. To free the fuel used in the blast furnace from it and also control the furnace regarding heat conditions is quite another matter. The fuel used in air furnaces must be selected with care—bad fuel is poor economy. Iron will be longer in melting, and while in the liquid state will quite readily absorb sulphur. High-grade coal is the cheapest and, while phenomenal runs have been made with an inferior quality coal, the iron produced has not been correspondingly phenomenal.

In purchasing pig iron, if there exists a doubt in the buyer's mind as to correct analyses, specify Bessemer limits all through.

You will then have an iron which may not be exactly what your melter wishes, but you will be safe. There should also be more leeway given in specifications for pig iron, but the manufacturers are not willing to become any broader in their views on account of what may be local ideas and practices. For years a concern have been making malleable in one way, and have been using the same grades, and are therefore unwilling to hazard anything on new analyses. But this cannot continue. The times are changing in malleables as they have in steel in the past, and the day will come when we will have to accept what is offered. Then the up-to-date concerns will be the only ones alive and doing business.

The question has often been agitated as to whether objectionable impurities in molten metal could be absorbed or eliminated in the air furnace by the use of a flux. The writer has made many trial heats in this direction, and with fair success. In charging heats a quantity of limestone was placed on the bottom, with a small percentage of fluor spar. After the charge was melted the first skimming was delayed to allow the limestone sufficient time to attack the silicon. This was accomplished, reducing same about 0.40 in furnace. The fluor spar acting upon the sulphur and phosphorus also gave the most encouraging results. There is, however, a great tendency for the limestone to cut the bottom and side walls, but with an extra coating of ground crucible shells this was avoided.

No better illustration may be had of the affinity of iron for absorbing sulphur than from the fact that a modern blast-furnace burden, which carries 0.035 sulphur, produces a metal having as high as 0.250 sulphur. This occurs, of course, when furnace is cold. The same may be said of an air furnace. When an inferior grade of coal is used the heat is slow coming up. There must be no liberty taken with sulphur above 0.045, if successful castings are to be produced.

ELECTRICALLY OPERATED 150-TON JIB CRANE AT NEWPORT NEWS SHIPYARD.*

By Walter A. Post.

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Together with the demands of the day for greater capacity, greater power and greater speed, as essential characteristics of the modern ship, there comes the dependent feature of greater weight, and, to the shipbuilder, the problem attendant upon this feature, namely, that of providing for the economical handling of these weights.

The plant of the Newport News Shipbuilding and Dry Dock Co., although well provided from its origin with appliances for handling material, was found in its later developments to be in need of apparatus more powerful and convenient than the 100-ton sheer legs which, to that time, had been used for handling the heavier weights installed on board ships during the fitting-out period.

The growing need of such apparatus had been for some time forcing itself upon the attention of the company, but it was only in the srping of 1896 that it was finally determined to undertake its provision, and steps were taken to ascertain from the experience and opinions of experts, both in this country and abroad, what general type of machine would most satisfactorily fill the particular requirements of the Newport News plant.

The fundamental requirements, briefly stated, were: Capacity to lift and place on board the heaviest single weight liable to be incurred in the probable development of modern ships; a field of operation, as large as practicable, in which these weights could be handled, and absolute precision within this field; a location

* Read in the Sixth General Meeting of the Society of Naval Architects and Marine Engineers.

accessible by the ordinary means of transportation from all parts of the yard; and, finally, that greatest factor defined in all projects by the broadest use of the word economy.

Careful consideration of these requirements lead to the adoption of a 150-ton revolving derrick, electrically operated and controlled, mounted on a steel tower supported in turn by pile foundations. The structure was located on one side of a pier 700 feet long, forming one side of a slip, in which a number of ships may be moored at one time and readily brought within the field of the derrick's operation. Two standard gage tracks over entire length of pier afford means of transportation from any part of the yard, and also direct connection to the main lines of the Chesapeake & Ohio R. R. System. The floor of the pier, 185 feet in width, furnishes ample room for the temporary reception of heavy pieces, castings, armor, etc., and permits, in addition, the assembling of much work within direct reach of the derrick, thus allowing assembled parts to be placed on board as a single member, relieving the tendency to overcrowd floor space in the shops and effecting a saving in cost over work as assembled on board ship.

The final design of the derrick was taken up about March 1, 1897, and in July, 1898, sixteen months later weights were being placed by it on board the battleships in course of construction at the yard.

Aside from the steel work in the tower, it was designed, constructed and erected by the Newport News Shipbuilding and Dry Dock Company, under the direction of Somers N. Smith, at that time general superintendent of the works. The design of the derrick itself, including steel tower, jib, hoists and machinery in general, was prepared by the steam engineering department under C. F. Bailey; the direct working out of plans and details being assigned to R. L. Lovell, of the same department. The successful completion and high efficiency of the whole machine attested both the care and skill of the designers and the workmanship of the yard force. The steel tower was furnished and erected by the Berlin Iron Bridge Company, of East Berlin, Conn.; while the foundations were designed and constructed under the direction of the author.

A brief statement as to size, capacity, range of operation, etc., may be of interest before proceeding to the description of particular details.

The derrick jib is capable of having its outer end raised or lowered, thus giving to the hoisting blocks, which depend vertically from this end, a movement not only of rotation about the center of the derrick, but also of translation in or out from this center. With the outer end of the jib in its lowest position the hoisting blocks will, on rotation of the derrick, describe the circumference of a circle 207 feet diameter; with the jib in its highest position these blocks, on rotation, describe the circumference of another concentric circle 88 feet in diameter, thus permitting the derrick to operate on weights lying anywhere within the circle ring whose maximum and minimum diameters are 207 feet and 88 feet respectively. The maximum load of 150 tons can be handled only within a ring whose maximum and minimum diameters are 147 feet and 88 feet respectively, but weights up to 70 tons may be handled throughout the entire field of operation. This feature of varying the radii at which the hoisting blocks can operate, constitutes a most important difference between the derrick under discussion and the 130-ton steam crane erected in 1893 on Finnieston Quay, Glasgow. In the Finnieston crane, which at time of its construction represented the ideas of best English practice, there is no variation in the radius at which the hoisting blocks are carried, and, in consequence, the field of operation becomes narrowed to a single line, the circumference of a circle described by the blocks on revolving the crane. The advantages of the Newport News derrick are obvious.

The maximum elevations, above mean high water, for the hoisting hooks in the high and lower positions of the jib are 118 and 69 feet respectively; this giving ample clearance vertically for any probable conditions.

Taking up the description of the several parts of the structure, it may be well to follow the actual order of construction and begin with the foundations.

A discussion of the conditions which serve to determine the choice between a masonry or pile foundation is obviously be-

yond the scope of the present paper, and it is sufficient to say that the decision to adopt a pile foundation was reached, not alone after the possibilities of masonry, but also of metal tubes and cylinders filled with cement, had been investigated at much length. The soil at the point of erection is eminently suited to the use of piles, and it is the author's belief, based on a number of years' experience in that locality, that a properly creosoted pile foundation would, under conditions imposed, have about 90 per cent. of its original strength retained after a period of twenty-five years. Assuming the probable life of the foundation to be twenty-five years, and recurring again to the governing factor of economy, we may, with pertinence, state that the cost of such foundation was about $8,000, and the time consumed in construction about two months; while the masonry foundation for the Finnieston Quay 130-ton crane cost in the neighborhood of $45,000, and required seventeen months to complete. It is apparent that the interest accumulations on the difference in cost for a period of twenty-five years is far more than sufficient to renew foundations and re-erect derrick.

The foundations adopted consist of four concentric rows of piles, driven vertically and spaced 3 feet center to center, measured on the circumference of each ring. One hundred and fifty piles were required for these rings, all carefully selected, straight, round sticks, measuring not less than 14 inches 6 feet from the butt, and not less than 9 inches at the small end. They were carefully treated with London ordinary dead oil, of approved quality, 16 pounds to the cubic foot, and then driven, under a 5,000-pound hammer, to an average depth of 28 feet into the hard bottom of the river. In addition to the above, seventy piles were driven at an angle of 30 degrees to the vertical and secured to the capping by galvanized-iron drift bolts, thus giving the entire foundation greater rigidity and stability. The caps are carefully selected live oak, 14 inches by 11 inches, laid in concentric circles on tops of piles, surmounted in turn by two thicknesses of heavy live-oak flooring, the lower flooring being laid radially across the caps, while the upper one has its lengths laid, similarly to the caps, along the circumferences of concen-

tric circles. The whole assemblage, of caps and flooring, is protected as much as possible from decay, and firmly secured to the piling by galvanized-iron drift bolts. It may be well to state, as a concluding remark on the pile foundations, that it is intended to fill the pier solidly around the space occupied by the derrick foundations, thus preserving the piling for an indefinite period from the possible attacks of the teredo.

Proceeding to the description of the steel tower: we have a structure cylindrical in general form, comprised of sixteen columns securely braced and anchored, through their shoe plates, to the pile foundations below, the columns being surmounted by a series of box girders to which is bolted the cast-steel track carrying the rollers on which the derrick revolves. The sixteen columns are equally spaced over the circumference of a circle 36 feet diameter and set square to radial lines through their centers. They are built up of two 15-inch channels, 70 pounds to the foot, well latticed on the sides, with batten plates, top, bottom, and midway their height, at which point horizontal and diagonal braces connect. The column shoe plates are seated on iron plates $1\frac{7}{16}$ inches thick, carried by the upper course of live-oak flooring, each shoe being anchored by twelve $1\frac{3}{8}$-inch bolts to the piles, if possible, and where not, to the pile caps.

To heavy box girders, surmounting the columns, are riveted at every other column the ends of lattice girders projecting radially from the center, at which point they connect to heavy gusset plates which serve to build up a central bearing for the 16-inch vertical pin used to center the derrick, and which serves, also, should unforeseen emergency require it, to prevent any lifting tendency of the derrick itself. Projecting outward and downward from the pin bearing, to the base of each alternate column above mentioned, are stiff angle braces, tied at their middle points to the top and middle point of columns by diagonal and horizontal angles. Diagonal tie rods, 2 inches in diameter, running from the top and bottom of the alternate columns, which do not carry radial girders, to the bottom and top of corresponding columns opposite, serve, with the above-mentioned angle braces, to rigidly connect and tie together the whole structure of

the tower. The circular turned cast-steel track, on which sixty-three conical cast-steel rollers travel, has a mean diameter 36 feet for the roller circle and is so beveled that the top elements of the rollers are always horizontal, thus insuring an easy turning motion. The rollers are held in place by two concentric circular rings, the inner one built up of plates and angle bulb, the outer one of plates alone, these rings being held in place by twenty-one 2-inch steel rods, radiating from the center pin casting, to which they are secured, and passing axially through every third roller and secured at the same time to both roller rings.

We have now reached the revolving structure or derrick proper, which may be, for convenience of description, divided into two members: the housing, a heavily framed structure, containing the generating and controlling machinery, operating platform and counterweight or ballast; to this is secured the second member, namely, the jib, which, carried by the housing and controlled by the power therein, carries in turn the sheaves and blocks through which all the hoisting power must be finally applied.

Recurring to the housing, a brief description will suffice to indicate its general character and note interesting features.

Resting on the conical rollers is a circular girder; on this is carried the heavy cross-girders which furnish supports and foundations for the generating motors, heavy gearing, drums, and other parts of machinery. In a central bearing is the 16-inch pin previously mentioned; at one end of the cross-girders is secured, by a 9-inch pin connection, the lower end of the jib, while at the opposite end of the girders rises the ballast tank containing 410 tons of pig-iron ballast. The ballast tank is built up of heavy floor girders, resting on and running at right angles to the cross-girders above mentioned. From the extremities of these floor girders rise the vertical ends of the tank, each end being a hollow box section and serving to transmit the weight of the ballast from the floor of the tank to the 10-inch pin connections at the top of the tank, from which points inclined struts are run downward and across to the ends of the cross-girders which connect with the lower end of jib. The ballast tank overhangs the circular girder,

and as only a portion of the weight of the ballast is required to balance the jib in its high position, the remaining weight of ballast is carried, in that case, by the overhanging girders, which are reinforced by brackets on the side.

The arrangement of ballast above described brings the center of gravity of the revolving structure always within a radius of $7\frac{1}{2}$ feet from the center, which, as the path of the roller bearings has a mean radius of 18 feet, gives a minimum factor of stability of 2.4. Thus, with the jib in its highest position and no load, the center of gravity is $7\frac{1}{2}$ feet behind the center, while with 150 tons load at $73\frac{1}{2}$ feet radius, or 70 tons load at $103\frac{1}{2}$ feet radius, the center of gravity is $7\frac{1}{2}$ feet forward of the center. As before referred to, the 16-inch central pin is provided with a top nut and secured below, which thus affords a further safeguard against tilting.

Turning, for a moment, to the jib, attention may be called to the endeavor to so arrange sheaves as to bring the minimum amount of bending and wear upon the pins. The member as a whole is a triangular truss, pin connected and with its long side in compression.

In taking up now the operation of the derrick, we will divide our remarks into three headings, corresponding to the three main movements, namely, revolution, elevation or depression of the jib, and the vertical movement of the hoists.

The derrick is revolved by duplicate sets of machinery, each consisting of one No. 800 General Electric railway motor, capable of developing 20 horse power, and driving, through means of a double-threaded worm and wheel of the Albro-Hindley pattern, a pinion which, engaging a horizontal circular rack on the outside of the tower, gives the required movement of rotation. The motors are series wound and controlled from a series parallel controller, giving high efficiency under starting conditions as well as at normal speed. The turning motion is very smooth and perfectly noiseless, and, as will be seen from the tests, requires very little power.

The racking movement of the jib is effected as follows: At the inner and upper apex of the jib is a 10-inch steel pin carry-

ing twenty-two cast-steel sheaves, each sheave of 5-foot pitch diameter. At the upper apex of the housing is another 10-inch pin carrying twenty-four similar sheaves. Leading over these two sets of sheaves, and sustaining the weight of the jib and load, are two 1¼-inch steel wire ropes; each rope being wound on alternate sheaves and each end of each rope brought down to separate drums, located below in the housing; this arrangement ensuring freedom from side twisting on the sheaves and also requiring each rope to take its share of the weight. The four drums, on which these ropes are wound, are arranged in pairs, each one of a pair taking opposite ends of the same rope, and each pair driven by a No. 2,000 General Electric series motor of 100 H.P., the power from the motor being transmitted to each drum through a separate train of gears. The drums are of cast iron, 5-foot pitch diameter, carried by 7-inch steel shafts. Each rope, having twenty-two parts, is strong enough to sustain and operate the jib when under maximum load, thus guarding against accident and enabling either motor to be disconnected, and the rope, which it controls, to be removed for repairs or renewal. The motors are series wound, which ensures each taking its proper share of the load.

Passing finally to the hoist, we have two main hoists, each of 75 tons capacity, and one 20-ton whip for lighter loads. The main hoists are each of twelve parts, 1¼-inch steel wire rope, leading over six sheaves, 5 feet pitch diameter, carried on a 10-inch steel pin at the outer end of the jib. The lead from these sheaves to the operating drum is carried down the jib on wooden roller runners. These drums, one for each hoist, are of cast iron, 8½ feet pitch diameter, carried on 7-inch steel shafts, and each driven through a train of gears, by a No. 2,000 General Electric 100-H.P. motor, series wound. These hoists may be coupled together and operated as one hoist of 150 tons capacity. The 20-ton whip is of three parts, 1¼-inch steel wire rope, carrying a single block and leading over two sheaves, carried, as are those for the main hoist, at the outer end of jib. The lead from these sheaves passes down the jib, over a single guide sheave, to a cast-

iron drum, 8½ feet pitch diameter, driven through a train of gears by a No. 2,000 General Electric 100-H.P. motor, series wound.

It will be noticed that electricity is used to generate the power required for all the movements of the derrick. The question involved in the choice as to the form of energy to be employed in such a machine cannot be fully discussed here, but the convenience of operation, ease of movement, and general efficiency of the present derrick attest the successful use of electricity in this case. Current is transmitted, over heavy, insulated copper wire, to fixed brushes, attached at the center and near the top of the steel tower. These brushes are arranged to bear against circular contact rings insulated from, but carried by, the center casting to which the roller rods are secured. Near the top of this casting are two more contact rings which transmit the current to a pair of brushes, fixed to the revolving part of the derrick, from which the current is delivered over heavy, insulated copper wire to the several motors. The current is delivered to the motors, under normal conditions, at a pressure of 220 volts.

Before concluding, it may be interesting to note a few particular features, and to give the result of such tests as opportunity has permitted up to the present time.

The brakes are a feature of considerable interest. These were required to occupy little space, be powerful and certain in their action, and to be automatic. This was accomplished by extending the ordinary band brake so that it wound four and one-half times around a brake cylinder carried on the shaft to which is keyed the pinion that meshes into the gear of the operating drum. This brings the brake in as direct connection with the load as possible and guards against accidents of the machinery. The brake cylinders are of cast iron, 30-inch diameter, with the wearing surface chilled. The band is of wrought-iron, 1 inch thick, 5 inches wide at one end, and tapering to 1¼ inches at the other. The broad end is firmly anchored, while the narrow end is secured to a lever carrying a weight of 200 pounds. When lowering the jib or the hoisting blocks, the direction of rotation for the brake cylinders is toward the small end of the band, so that the friction, produced by the weight, between the cylinder and

TESTS OF THE 150-TON ELECTRICALLY-OPERATED JIB CRANE AT NEWPORT NEWS SHIPYARD.

MOVING JIB.

Movement.	Net load.	H.P.	Time.
			minutes.
From lowest to highest position	0	89.0 to 64.1	6.9
From highest to lowest position	0	0. 0.	5.56

HOISTS.

Hoist.	Net load.	Speed in feet per minute.	H.P. delivered to motor.	H.P. required to hoist load.	H.P. absorbed by machinery.	Efficiency.
	long tons.					*per cent.*
Right-hand main	68	6.05	54.3	28.0	26.3	51.5
Right-hand main	0	10.12	29.2	0	29.2	0
Left-hand main	66	7.03	61.9	31.4	30.5	50.9
Left-hand main	0	9.08	30.65	0	30.65	0
Whip	19.2	52.3	88.9	68.3	20.6	76.8
Whip	0	84.3	35.35	0	35.35	0

REVOLUTIONS.

No. of test.	Net load.	Total weight on rollers.	Center of gravity from center of revolution.	Time of one revolution.	H.P. delivered to motors.
	long tons.		*feet.*	*minutes.*	
1	134	910	4.28	3.38	10.71
2	68	845	2.22	3.36	11.17
3	0	775	1.47	3.04	11.15
4	0	775	7.00	3.04	11.15
5	0	775	4.49	3.55	10.65

band, causes the band to wind tight on the cylinder and stop rotation. In hoisting, the brake releases itself, the friction lifting the weight and uncoiling the band, while any tendency to rotate in the opposite direction causes the weight to fall and the band to tighten. To release the brake it is only necessary to lift the weight, which is done by means of a wire connecting with a lever in the operating house, the lever being always within reach of the operator, and the brakes always in operation except as released by continuous pull on the lever.

The operating station is directly underneath the lower end of the jib, overlooking directly the weights to be handled, and encased with glass front as a protection against the weather. The controllers for the several motors are within easy reach of a single operator, who is thus given convenient and absolute control over the varied movements of the derrick. The ropes for the hoist and racking movement are all of plow-steel wire, $1\frac{1}{4}$ inches in diameter, of six strands of thirty-seven wires each, with hemp center and very flexible. Each rope has a breaking strength of 100,000 pounds. The gears throughout, except the worms and those supplied with the motors, are of cast steel with cast teeth, the pinions being full shrouded. These gears work very smoothly and show a high efficiency.

The difference in power required for the two main hoists is explained by the fact that all gears, except the pair on motors, have cast teeth and, consequently, variable friction. All tests were made soon after the completion of the derrick, and still better results may be anticipated when opportunity has been given for the gears to wear smooth.

The jib has been both raised and lowered with loads up to 66 tons, but, as this was done only in regular course of work, no data was taken. In hoisting, the required power decreases as the moment of the jib decreases. In lowering, power is required to start the machinery, after which the weight of the jib will keep it in motion.

The variation in speed and power required was probably due to influence of the wind, as the observations were taken on different days, with different velocities of the wind. Tests Nos. 3 and

4, taken as near as possible, show no difference in result, although the position of the center of gravity varied considerably.

The safety factors attained in the various members are as follows:

Lower struts or legs,	10
Tension members—eye bars,	9
Inclined struts,	7
Wind bracing,	12
In hoisting ropes,	7
In tower columns,	7.5
In tower wind bracing,	15

The total weights in long tons are as follows:

Derrick on rollers (no load),	775
Derrick on rollers (maximum load),	925
Entire structure on piles (no load),	926
Entire structure on piles (maximum load),	1,076
Maximum load for piles, taking vertical piles only and considering eccentricity of loading,	9.04

A brief summary of tests is given in table.

In concluding this paper it may be said that the most difficult problem encountered, in the design of the derrick, was that of providing a safe and efficient way of operating the jib, and in so far as the author knows, the method adopted is, considering the large forces involved, something of a novelty. The results attained and the efficiency of the mechanism would indicate that the problem had been well solved, and that the idea here carried out might, with advantage, be extended by other designers to future problems.

MACHINE SHOP NEW YORK NAVY YARD. VIEW FROM EAST GATE.

NOTES.

THE DESTRUCTION OF THE MACHINE SHOPS OF THE NEW YORK NAVY YARD BY FIRE.

The machine shops of this yard were totally destroyed by fire between the hours of 6 and 10 P. M., February 15, 1899. The building is a three-story structure, brick and granite walls, the first and second floors being occupied by machine shops and the third floor by the pattern shop.

The fire seemed to originate in the office on the second floor, and spread all through that floor with extraordinary rapidity. The city fire department responded as promptly as possible with twelve engines, one water tower, the fire boat *Seth Lowe*, and four hook and ladder companies. Great difficulty was experienced in getting engines and hose in place owing to deep snow on the vacant ground leading to hydrants. Here very valuable assistance was rendered by relief parties from the *Massachusetts*, *Vermont*, *New Orleans*, *Newark* and *Supply*, and by the yard stable force and horses. The yard officers and naval employees were on the ground and gave valuable assistance. With great difficulty the foundry on the opposite side of the street from the machine shop was saved. The walls of the main building fell, but the corner towers remained standing. The boiler shop was only slightly injured, and the power-house boiler room was saved. A horizontal engine used for running the dynamos was saved, although the falling walls ruined the dynamos themselves. As there was a line of shafting from over this engine leading to the boiler shop, it was possible to belt up and run this engine by the 18th for driving the tools in the boiler shop.

The east wing, which was used as an erecting shop, was considerably damaged. All the machinery and tools in the main shop were ruined.

An estimate made on the loss of the buildings, which merely indicates the book cost of the original buildings with improve-

ments, and not that which is necessary for replacing, was as follows:

Main building,	$621,496
Boiler-shop wing,	5,000
Erecting shop,	2,000
Boiler house,	1,800
Office building,	300
Electric-light plant,	3,200
Cost to clear site,	7,000
Total,	$640,796

Plans are being prepared for the erecting of new shops, the front wall to be on the line of that of the original shop, but the front building to be 130 feet wide, the east wing to be 130 feet wide also, and the west wing to remain same width as it now is, which is approximately 90 feet, and both wings to be extended 160 feet farther than the original lines. This, with modern tools and electric traveling cranes, will probably be the finest machine shop in the world.

INVESTIGATIONS OF A BLOWING FAN.

During the last three years Professor Carpenter, of Cornell University, has been making investigations of fans, and at the annual meeting of the American Society of Heating and Ventilating Engineers, held last month in New York city, presented the principal conclusions he had reached, in a paper under the above heading, the "Engineering News" of February 2d, 1899, thus summarizes the results:

The first investigation established the following propositions, which were advanced some years ago by Murge.

First. The volume of air delivered varies as the speed of rotation.

Second. Difference of pressure varies as the square of the speed.

Third. The power required varies with the cube of the speed.

The object of the later investigations was to determine the

most efficient form of fan blade, and also the effect due to variation in size of outlet and inlet. For the purpose of testing fans with different shaped blades, the radial blades were removed and bent blades substituted, which were radial for a distance of 7 inches, then curved in an easy bend in a direction approximating tangential at the outer extremities. The bent blades were arranged so that they could be operated with the curved end run in a backward or forward direction. The area of the plane blades in the direction of the radius was 1.5 square feet, the projected area of the curved blades on a radial plane was 1.37 square feet. As compared with the radial blades there was a loss in quantity of air delivered for a given rotative speed of nearly 25 per cent. when the blades were bent backward, and but little loss when the blades were bent forward. As normally constructed there was but one inlet to the fan, which was 22 inches in diameter. For a portion of the experiments a second inlet of the same size was constructed on the opposite side, so that experiments were made with the radial blades with two inlets.

Relation between horse power delivered to fan and outlet area: The blades bent backward take the smallest amount of power for a given outlet; the radial blades an intermediate amount and the blades bent forward the greatest amount. The power required for the radial type of blades for very small openings was decreased, but for larger openings was increased by doubling the inlet opening, which effect is accounted for by noting that the quantity of air delivered is greatly increased for the larger openings.

Relation between the quantity of air delivered in cubic feet per second and the area of outlet opening for a constant speed of 500 revolutions per minute: With a single inlet opening the greatest quantity of air for a given outlet area was obtained with the fan which had the blades bent forward, the amount delivered by the radial blade being intermediate, that by the blades bent backward the least. The effect of doubling the inlet area was to increase the quantity of air delivered by the radial fan very materially for the larger openings.

Variation in the quantity of air delivered per horse power in cubic feet per second due to changing area of the outlet, and

consequently the back pressure: The best results were obtained from the fan with blades bent backward. Rounding off of the tips of the blades and bending them backward decreases the amount of air delivered, and also the power required to drive the fan, as compared with the other conditions, but the power required to drive the fan is reduced more than the delivery of air, consequently the air delivered per horse power is the greatest, or, in other words, the efficiency of this type of fan is the greatest of the types compared under the same condition of inlet. Doubling the area of the inlet, for the fan with radial blades for a small area of outlet or for back pressures much exceeding one inch of water, made no special change in the results, but for large area openings or when the pressure is less than about one inch of water, much more air is delivered.

Relation between the velocity of delivery, the back pressure and the area of outlet: For the two conditions of the radial blades and blades bent forward, the velocity of the discharge exceeds the peripheral velocity of the fan when the back pressure corresponds to about 1.6 inches for the case considered. For a higher or a lower back pressure the velocity becomes less.

The type of blade which gives the lowest velocity of air gives the best result as to the quantity of air per horse power, from which it would appear that the most effective fan is the one which delivers the air at the lowest velocity. With the type of blade bent backward at the tips, the maximum velocity lacks 11 feet per second of reaching the peripheral velocity of the fan; the other three types exceed the fan velocity at the maximum point, as already mentioned. It is probable that the reason why the blades bent backward do not give so high a velocity is due to the slipping of the air over the tips of the blades.

Relation between efficiency of the fan, the area of outlet in square feet and the pressure produced by the radial type of fan: Each type of fan has a condition of maximum efficiency with constant speed which occurs under the condition of the test with the fan with blades bent forward when the back pressure is about 1.7 inches of water, for the fan with the radial blades when the pressure is about 1.5 inches, and for the fan with blades backward

when the pressure is about 1.4 inches. The fan with the blades bent backward has a maximum efficiency of about 43.5 per cent.; the fan with the blades bent forward has a maximum efficiency of 37 per cent., and with the radial blades a maximum efficiency of about 33.6 per cent. The fan with the radial blades double inlet had a maximum efficiency of about 45 per cent. which occurs, however, with a low pressure of air.

Relation between pressure in delivery box and the area of outlet, when the fan is working at a constant speed: The fan with blades bent forward gives the highest pressure, and the fan with blades bent backward gives lowest pressure, but for openings of the delivery tube much in excess of the area of the blade, the fan with the double inlet shows the greatest pressures. In all cases that the pressure is greatest when the delivery of air is least. Buckle* gave as results of his experiments the following formula for expressing the relation between the pressure produced and the peripheral speed, as reduced by Kent in his "Pocket Book for Mechanical Engineers:"

$$v = 60\sqrt{p}$$

in which p is the pressure expressed in inches of water and v is the peripheral velocity of the fan in feet per second. The pressure deduced by Buckle's formula would be obtained under conditions like those in the experiment cited when the area of discharge opening expressed in percentage of the area of the blade was 15 per cent. when the blades were bent backward, 18 per cent. when the blades were radial, and 25 per cent. when the blades were bent forward.

I have found by a comparison of Buckle's formula as above with actual tests that the maximum pressure which is produced by a given peripheral velocity is greater than that stated by Buckle by an amount which varies in different conditions from 1 to 15 per cent. The maximum pressure which may be produced is the only one which can be considered as positively depending upon the peripheral velocity, since the actual pressure in any given case depends very largely upon the resistances

* Paper before Institute of Mechanical Engineers, England, 1847.

to a free discharge corresponding in the case of the experiments cited to the area of outlet. The more freely the air is discharged, or, in other words, the less resistance, the less the pressure that will be produced by the fans. Buckle's formula, however, is usually a safe one to employ, since the pressure given by it is less than can be realized in practice, provided the resistance to the flow of air is at a maximum.

SHIPBUILDING AT NAGASAKI.

The "Marine Record" publishes the following notes communicated by Charles B. Harris, Consul at Nagasaki, Japan.

There has recently been delivered to the Nippon Yusen Kaisha what is said to be the largest steamship that has ever been launched outside of American or European waters.

The vessel is the *Hitachi Maru*, built to order by the Mitsu Bishi Company in its shipbuilding yards at this port. She was about twelve months in the builders' hands, and before delivery to owners was subjected to survey by an officer sent especially from London. Her class is Lloyds' 100 A1, approved by the shipbuilding encouragement law of the Imperial Japanese Government; type, 3 decks; material of hull, steel; length, 462 feet; beam, 49 feet 2 inches; depth, 33 feet 6 inches; draught, average, 25 feet; gross tonnage, 6,150 tons; displacement, 11,660 tons; freight capacity, 7,150 tons; engines, triple-expansion, double screws; boilers, 4; indicated horse-power, 3,500, speed, 14 knots.

The Mitsu Bishi Company will immediately commence the construction of a sister ship to the *Hitachi Maru* for the Nippon Yusen Kaisha.

There has also been opened at this port by the Mitsu Bishi Company a new granite dock, of an extreme length of 371 feet; length on blocks, 350 feet; breadth, 78 feet, with draught of 23 feet at high water. This dock is close to the engine works of the company, which have been largely improved by the extension of the buildings and by the addition of machines of the latest type, including a large overhead crane of 30 tons carrying power

in the erecting shop and new sheer legs of 80 tons capacity on the jetty for the landing and delivery of heavy boilers and machinery. The boiler shop, with its 105-ton riveting machine and other appointments, is now equal to the heaviest kind of work. A powerful steam hammer has been added, as well as other improvements necessitated by the increasing requirements of vessels and the larger type of ships now navigating the eastern waters. Rails have been laid from the sheers to and around the works with turntables, etc. A new molding shop of 50 tons capacity, with all the modern improvements, has been erected.

The ship-building yard has been laid out for vessels up to 500 feet in length, and ground enough has been added for four vessels to be on the stocks at one time. Ships of 300 to 450 feet are now being built. The molding loft, with carpenter shops underneath, has been greatly increased in size.

The No. 1 dock has been lengthened so that it can now take in vessels of the heaviest draught, up to a length of 500 feet; while the patent slip and siding can take vessels of over 1,000 tons register. The docks will accommodate five vessels of ordinary size at one time.

The Mitsu Bishi Shipbuilding Company, when busy, employs 2,000 men; it pays laborers 60 sen a day, which is 30 cents gold; skilled workmen receiving from 1 yen (50 cents) per day upwards. This company is gradually advancing the pay of employees, for the reason that the cost of rent, fuel, clothing and food to all classes has so increased as to render an advance necessary. The cost of living among all classes has increased enormously at this port—entirely out of proportion to the advance in wages and salaries.

TRIPLE-SCREW WAR STEAMERS.

It is doubtful if any of the new vessels afloat in other navies ever developed the same steaming qualities as the *Minneapolis* when she made over 24 knots on part of her official run between Boston Bay and the Maine coast. The *Kaiserin-Augusta* and the *Gefion* have triple screws and were built about the same time, both capable of about 24 knots. Germany is building seven new

vessels of the *Freya* class, all of which are to have three screws. Each ship is to displace 5,650 tons, have a sustained speed of at least 20 knots on a horse power of 10,000. They will all be cruisers. A larger vessel is the armored cruiser *Fürst Bismarck*, which is to have three screws, and is designed for a displacement of 10,600 tons, a horse power of 13,000, and is expected to make 19 knots with each. None of these vessels seem deserving of being classed with the *Minneapolis* and *Columbia*, which have for years been considered the fleetest war vessels of their displacements in the world. France is building five battleships which are to have three screws, three of which are to be like the *Charlemagne*, her most powerful class, and will be ready for service shortly. The *Charlemagne* and *Saint Louis* are regarded by the experts of France as the best type of battleship building for the navy, and the success of the three-screw system in ships of such great displacement is awaited with some anxiety by her experts, who have not had full confidence in it. The displacement of these ships is 11,275 tons each, horse power 15,000, and a speed of 16 knots. They are to have the same speed with three screws that the new battleships recently contracted for by our Navy Department are required to develop with twin screws.

Two other battleships, of the *Henry IV* class, are also building and will be fitted with triple screws. These are of 9,000 tons displacement, 11,500 horse power and a speed of 18 knots. Ten armored cruisers are either building or practically completed, which are all to have triple screws, high speed and enormous steaming radius, and be in all respects equal to the best of their type in the world. The *Jeanne d'Arc* will be the best of these vessels and perhaps the most formidable if not the fleetest armored cruiser in the world, equaling the immense vessel of this size lately turned out by British shipyards. This new French vessel is to have a displacement of 11,270 tons, or about equal in size to the American battleship *Iowa*, but her horse power is to be at least 28,500, or 11,000 greater than that of the *Columbia* or *Minneapolis* and three times that of the *New York*. A speed of 23 knots is expected, and if she equals this the *Minneapolis* will have her first rival. Six vessels of the *Montcalm* class and also

of the armored cruiser type are building with three screws, on displacements of 9,517, horse power of 19,600, and a speed of not less than 21 knots. Three more armored cruisers of the *Desaix* class are also under construction with triple screws, each to be of about 7,700 tons displacement, 17,000 horse power, and a speed of 21 knots.

In addition there will be two commerce destroyers, the *Chateaurmenault* and *Guichen*, of displacements of 8,300 tons, horse power of 24,000, and a speed of 23 knots. These are in many respects similar to the *Minneapolis* and *Columbia*, although larger and with greater machinery power. They are expected by the French designers to be the fastest vessels of the navy outside of torpedo boats. Russia is also building large warships with three screws. Two of these are battleships, the *Oslabya* and *Pereswich*, which are designed to be her most formidable warships, and are expected to be the fleetest afloat. These vessels as contracted for are to be of 13,560 tons and 14,500 horse power, which it is believed will give them a speed of about 20 knots. Another immense vessel building with three screws is to have a displacement of 14,000 tons and a speed of 23 knots. She is said to be of the commerce-destroyer type, although the Navy Department has no official description of the vessel. Four other ships are also building, of the *Diana* class, to have displacements of 6,500 tons, 11,000 horse power, and a speed of 21 knots.—"American Shipbuilder."

EXPERIMENTS ON THE FLOW OF STEAM THROUGH PIPES.

At the December meeting of the American Society Mechanical Engineers in New York Professor R. C. Carpenter, of Cornell University, presented an interesting and valuable paper on the above subject illustrated by a series of tables, one of which is here reproduced, showing the delivery in pounds per minute by pipes of given lengths and diameters, taking an absolute pressure of 100 pounds as initial standard and allowing a drop of only one pound. It affords a ready method of closely approximating pipe sizes in getting up pipe plans for steam plants, as well as for criticising existing lines of piping.

FLOW OF STEAM IN PIPES. DELIVERY IN POUNDS PER MINUTE BY PIPES OF GIVEN DIAMETERS AND LENGTHS.

(Absolute pressure, 100 pounds; drop in pressure, 1 pound.)

Calculated by E. C. Sickles.

Diameter in inches.	Length in feet.																							
	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600
¾	2.20	1.55	1.27	1.10	.983	.898	.831	.700	.733	.698	.659	.633	.611	.589	.568	.550	.532	.518	.506	.491	.481	.468	.457	.450
1	4.40	3.10	2.54	2.20	1.96	1.79	1.66	1.55	1.46	1.39	1.32	1.26	1.22	1.17	1.13	1.10	1.06	1.03	1.00	.982	.962	.932	.914	.900
1¼	9.76	6.90	5.63	4.88	4.36	3.93	3.69	3.44	3.26	3.08	2.92	2.81	2.72	2.62	2.52	2.44	2.36	2 29	2.24	2.18	2.13	2.07	2.03	1.96
1½	13.94	9.29	7.64	6.52	5.83	5.83	4.95	4.62	4.35	4.14	3.92	3.77	3.62	3.50	3.36	3.26	3.16	3.07	3.00	2.91	2.85	2.77	2.72	2.67
2	30.54	21 6	17.6	15.2	13.6	12.50	11.58	10.8	10.2	9.82	9.32	8.82	8.40	8.37	7.87	7.63	7.40	7.18	7.01	6.81	6.68	6.51	6.36	6.23
2½	50.8	35.9	29.3	25.4	22.7	20.8	19.2	17.9	16.9	16.2	15.2	14.62	14.4	13.6	13.1	12.7	12.3	11.9	11.6	11.3	11.0	10.7	10.5	10.4
...	50	100	175	250	325	400	475	550	625	700	775	850	925	1,000	1,075	1,150	1,225	1,300	1,375	1,450	1,525	1,600	1,675	1,750
3	65.17	46.0	35.0	29.2	25.6	23.0	21.2	19.6	18.4	17.4	16.5	15.8	15.2	14.5	14.0	13.6	13.1	12.7	12.4	12.10	11.82	11.5	11 2	11.0
3½	98.3	69.5	52.7	44.6	38.6	34.7	31.9	29.6	27.7	26.3	24.92	23.8	22.8	22.0	21.3	20.5	19.8	19.2	18.6	18.2	17.8	17.4	16.9	16 6
4	138.1	97.6	73.8	61.8	54 2	48.8	44.8	41.5	39.1	36.7	35.0	33.5	32.1	30.8	29.8	28 7	27.8	27.1	26.3	25.6	25.0	24 4	23.8	23.3
4½	187.9	132.9	102 0	84.1	73.8	66.45	61.2	56.6	53.1	50.1	47.7	45 6	43.7	42.0	40.51	39.2	38.0	36.75	35 75	34.75	34.0	33 2	32.4	31.8
5	255.6	180.7	136.2	114.3	102.2	90.3	83.3	76.9	72.1	68.2	65.1	62.1	59.6	57.1	55.1	53.2	51.6	50.0	48.6	47.2	46.3	45.2	44.2	43.2
6	419.4	296.5	224.1	187.2	164.2	148.2	136 1	125.8	118.4	111.8	106.8	101.8	97.3	93.7	90.2	87.2	84.2	82.2	79.7	77.6	75.7	74.1	72.2	71 0
...	50	100	175	250	325	400	475	550	625	700	775	850	925	1,000	1,075	1,150	1,225	1,300	1,375	1,450	1,525	1,600	1,675	1,750
7	618	437	330	276	242	218	200	186	174	165	157	150	143	138	133	129	125	121	118	115	112	109	107	104
8	890	624	472	394	346	312	286	266	249	236	224	214	205	197	190	184	178	173	168	164	160	156	152	149
9	1,206	853	644	539	473	426	391	363	341	322	306	292	280	269	260	251	243	236	230	224	218	213	208	204
10	1,592	1,126	851	712	624	563	516	480	450	425	404	386	370	356	343	332	321	312	303	295	288	281	275	269
11	2,046	1,447	1,093	915	803	723	664	617	574	546	519	496	476	457	441	426	413	401	390	380	370	361	353	346
12	2,575	1,887	1,428	1,192	1,044	943	852	803	752	714	679	648	620	598	575	557	539	523	509	494	487	472	461	451
13	3,165	2,238	1,692	1,415	1,242	1,119	1,027	954	891	846	804	767	736	707	682	660	639	620	603	588	573	559	547	535
...	50	100	200	300	400	500	600	700	800	900	1,000	1,100	1,200	1,300	1,400	1,500	1,660	1,700	1,800	1,900	2,000	2,100	2,200	2,300
14	3,838	2,714	1,920	1,567	1,357	1,213	1,108	1,025	959	904	858	818	783	752	725	700	678	658	639	622	606	592	578	566
15	4,596	3,250	2,300	1,873	1,625	1,453	1,327	1,228	1,149	1,083	1,028	980	938	901	868	839	812	788	766	745	726	709	693	678
16	5,030	4,000	2,830	2,315	2,000	1,785	1,638	1,513	1,413	1,333	1,268	1,208	1,153	1,108	1,072	1,034	1,000	972	945	916	895	834	854	834
17	6,375	4,500	3,210	2,635	2,250	2,021	1,841	1,702	1,591	1,500	1,424	1,357	1,302	1,248	1,200	1,162	1,124	1,087	1,061	1,033	1,006	982	962	940
18	7,370	5,211	3,685	3,008	2,605	2,330	2,128	1,970	1,843	1,737	1,648	1,571	1,504	1,445	1,393	1,345	1,302	1,264	1,228	1,192	1,165	1,137	1,111	1,087
19	8,472	5,992	4,237	3,459	2,996	2,680	2,447	2,265	2,119	1,997	1,895	1,807	1,730	1,662	1,602	1,547	1,498	1,453	1,412	1,374	1,340	1,307	1,278	1,249
20	9,240	6,838	4,835	3,948	3,419	3,059	2,793	2,585	2,418	2,279	2,163	2,062	1,974	1,897	1,828	1,766	1,709	1,658	1,612	1,569	1,529	1,492	1,458	1,426
22	12,365	8,743	6,183	5,048	4,371	3,910	3,570	3,278	3,093	2,914	2,765	2,627	2,524	2,406	2,337	2,257	2,185	2,121	2,061	2,005	1,955	1,908	1,864	1,823
24	15,943	11,308	7,990	6,535	5,650	5,065	4,522	4,435	3,995	3,769	3,580	3,418	3,271	3,141	3,023	2,921	2,820	2,750	2,665	2,585	2,535	2,472	2,415	2,361

THE PURCHASE OF SECOND-HAND BOILERS.

"Engineering" of December 9, 1898, notes the following conditions in England surrounding the matter of sale of second-hand boilers:

The Board of Trade investigation regarding the recent boiler explosion at Norwich, again draws attention to a matter of importance not only to steam users, but to the general public. From time to time we have reported the occurrence of explosions from miserable little boilers fit only for the scrap heap, but which have been sold and resold, with an utter disregard of the fact that they were dangerously defective, and that on being set to work they might explode at any moment with the most serious consequences. Given a practically worn-out boiler, a broker desirous of effecting a sale, and a purchaser on the look out for a cheap bargain, and too ignorant or too penurious to have an examination made to ascertain whether or not the boiler he proposes to purchase is safe to work, and we have all the essential elements of mischief. This has occurred on various occasions, as shown by the Board of Trade official reports, and the danger apparently remains as imminent to-day as it did when the Boiler Explosions Act was instituted, notwithstanding the fact that in several instances brokers and purchasers alike have been censured, and mulcted in penalties at the formal investigations.

We have from time to time met with many cases in which worthless boilers have been purchased at second, third or fourth hand; and, whatever the brokers may have known, the purchaser has been entirely ignorant of the danger that existed, although probably the low price that he paid should have given him warning and led him to suspect that all was not right.

Some time ago a boiler of weak and antiquated construction, which had seen long service and certainly deserved oblivion, was condemned by an examiner of undoubted ability, and was pulled out and sold to a dealer in machinery. The dealer did not cut it up; far from it, but he gave it a coat of paint, put in a few new rivets here and there, and sold it to a respectable shipping firm, who set it neatly in brickwork at the basement of their

large warehouse, situated in the heart of a populous city. An insurance company was called in to make an examination before starting work, and the inspector at once recognized in the boiler his old acquaintance which he had condemned some months previously, but which had been purchased by the new firm, doubtless in the belief that they were getting a serviceable article. Needless to say, the boiler was again condemned, and was removed by the broker who, on an action at law being threatened, returned the purchase money. This is by no means a solitary case, and others have occurred in which the danger has not been revealed until too late for a remedy.

The explosion at Norwich is an illustration of the unfortunate carelessness which too often accompanies the transaction of buying second-hand boilers. A Manchester contractor was in want of a boiler to drive a mortar mill in connection with the erection of a new technical school at Norwich, the Corporation having accepted his tender. Seeing an advertisement in which a boiler and a mortar mill, described as "strong" were offered, he corresponded with the firm who had them on sale, and at length became the purchaser. They were brought to Norwich, and on the first day steam was got up the boiler exploded, killing a lad and injuring several other persons.

The boiler, which was stated to be of considerable age, was a small one of vertical construction. The crown of the fire box was not efficiently tied to the crown of the shell, as is usually the case, by an uptake or other means, inasmuch as the gases after leaving the fire box passed into a smoke box at the back and thence to a chimney. Apparently through weakness the crown of the fire box had bulged downward some 4 inches or 5 inches, and this defect was noticed by two or three of the men who were engaged in coupling the boiler to the engine, and who stated at the official investigation that they duly reported the fact to those most concerned. No notice, however, appears to have been taken, and the warning passed unheeded. It is true that a water pressure of 100 pounds was put on with a view, it was stated, "of detecting leakage," but no examination of the fire box was made either before, during, or after the test, so that was utterly worth-

less and possibly misleading. When set to work, the boiler gave a practical protest by bursting; the weak fire-box crown collapsed, with the serious results we have mentioned. The surveyor to the Board of Trade informed the Commissioners that the pressure at which the boiler exploded was 95 pounds, and that had it been submitted to examination by the Board of Trade "it would not have been passed to work at any pressure whatever." The purchaser endeavored through his counsel to convince the court that when he saw the word "strong" used in the advertisement, he took it to apply to the boiler. The broker, on the other hand, said it only applied to the mortar mill, and that it was the duty of the purchaser to have the boiler examined and to assure himself of its safety. After an exhaustive inquiry lasting three days, the presiding commissioner took the broker's view of the matter, and practically exonerated every one except the purchaser, who had, he said, displayed great negligence in not having an inspection of the boiler made by a competent person. The purchaser was, he said, seriously to blame, although he had not acted from any unworthy motive, and he was ordered to pay the sum of £100 toward the costs of the investigation.

We accept this ruling, and are quite prepared to believe that both the seller and the purchaser were unaware of the dangerous condition of the fire-box crown. But we submit that ignorance is by no means a valid excuse, that both parties were seriously to blame, and that both should have shared the penalty. A broker, even in ignorance, has no moral right to sell to a purchaser, equally ignorant and careless, an article which, on being used, may fail, and deal death and destruction around. The broker in this case displayed great earnestness and shrewdness in urging on the purchaser that he would get a good bargain, as the mill was a very strong or "heavy" one. How was it, then, that he had been so lamentably careless in buying so defective a boiler, and subsequently offering it for sale in its dangerous condition, without any examination, without a word being said as to the fitness to drive the "heavy" mortar mill, and without advising the purchaser to make his own examination and obtain his own guarantee of safety? One would

have thought that common sense would have led the broker, and also the purchaser, to ascertain beyond all doubt that the boiler was fit to effectively drive the "strong" mill, which, being admittedly heavy, would naturally require a fair pressure of steam. But there was no common sense in the transaction; the question of safety or of a safe working pressure does not appear to have been considered, and the fact that the mortar mill was a strong one monopolized the attention of the parties.

The case seems to be full of unintentional misleading and misunderstanding, but the purchaser has had to pay dearly for the omissions of which he was guilty. In future those who contemplate buying second-hand boilers would do well to remember that, according to the ruling above stated, the onus of proof of safety rests upon themselves. By the judgment of the Board of Trade Commissioners just given it would appear that a broker offering for sale a defective boiler may, by showing that he was ignorant of danger, and that it was the purchaser's duty to satisfy himself that the boiler was safe, is relieved of responsibility, and practically acquitted of blame should an explosion occur. This may be good law, but some people may think it is bad justice. In some previous Board of Trade investigations brokers have been censured for selling unsafe boilers, and have had to pay a portion of the costs. This, we think, is but fair. Where so important an apparatus as a steam boiler is concerned, on which so much depends, there should be intelligence and care on the part of the salesman as well as on the part of the purchaser. If brokers wish to relieve themselves of responsibility, it would be well, when offering boilers for sale, to plainly tell their customers that they give no guarantee that the boilers are safe, but that they must look to this point for themselves by calling in a competent authority to make an effective examination.

The question of compulsory inspection has for the present apparently gone to sleep, but it certainly is a matter for regret that worn out and dangerous boilers can be sold and bought without let or hindrance, and set to work by anyone and any where, and in close proximity to crowded streets or important public buildings. If Parliament cannot take the matter up, what is there to

prevent our town or district councils, with whom rests the responsibility for the erection of buildings within their jurisdiction, passing a rule or by-law requiring that any steam boiler put up in connection therewith should possess a certificate of safety granted by some examiner recognized as competent? This, we think, would only be a reasonable precaution, and would tend to reduce the risk of a repetition of the Norwich explosion.

Meantime it rests with the Board of Trade to consider the question whether the end in view may not be assisted by making ignorant or careless brokers, who have sold boilers which have subsequently exploded, share the official censure and the costs of the formal investigations along with the purchasers. It is wonderful how ignorance is sometimes dispelled when the pocket is approached, and if a few careless salesmen were heavily fined, as well as the equally careless people who buy their wares without the necessary inquiry and inspection, it is very probable that under a sense of increased responsibility greater care would be taken by all concerned in such transactions.

INCREASE OF THE STRENGTH OF STEEL A FEW DAYS AFTER MANUFACTURE.

In the discussion of Mr. W. R. Webster's paper on Specifications for Structural Steel and Rails, read before the Franklin Institute, Mr. A. A. Stevenson, of the Standard Steel Company, Burnham, Pa., gave some interesting results of tests showing that the strength of railway tire steel is increased by allowing a few days time to elapse between the time the product is finished and the tests are made. We quote from the Journal of the Franklin Institute of January, 1898:

"You state that 'the quality of steel depends (1) on its chemical composition: (2) on the treatment it received in the course of manufacture.' I would go a step further, and say that, in my opinion, as far as open-hearth steel is concerned, the physical results, to a certain extent, depend on manipulation of the bath in the furnace.

"Concerning the relations between the chemical composition

and physical results, I must say I have been somewhat surprised to find how close this relation is. The point in question has been brought out strongly in test work we have recently done on some tires made for a foreign government to a rather difficult specification.

"I heartily agree with the effort to have the conditions under which tests are made reduced, as far as possible, to a standard. In my own experience, I have found a great many tests that were practically valueless for comparative purposes on account of unknown or varying conditions.

"I think it is desirable not only to have dimensions of test piece and pulling speed standard, but also important to have a record of the period elapsing between the time the product is finished and tests are made. That a change takes place in steel after finishing, which materially affects the physical results, cannot be questioned.

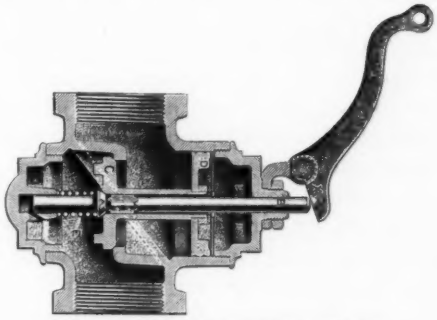
"In connection with above, the following figures may be interesting. Test pieces were all cut from tires and duplicate tests, as far as possible, from the same part of the tire, as, owing to section of a tire and process of manufacture, tests from different parts of same section show a variation.

Elastic limit.	Ultimate strength.	Elongation.	Reduction.	Remarks.
		Per cent.	*Per cent.*	
53,490	107,460	15.00	19.20	Pulled within three days after tire was made.
56,037	108,700	16.30	24.30	Ten days later.
50,940	99,590	14.00	22.20	Pulled within three days after tire was made.
53,000	103,464	18.00	27.40	Ten days later.
56,037	111,050	10.00	12.37	Pulled within three days after tire was made.
61,130	111,410	15.00	21.50	Ten days later.
70,370	121,250	11.00	14.01	Pulled five days after tire was made.
71,980	121,970	14.00	17.89	Seven days later.
65,080	121,470	11.50	13.55	Pulled seven days after tire was made.
64,400	121,160	13.00	16.30	Fourteen days later.

"The tests were all pulled at the same speed. The dimensions of the first six test pieces were 2×0.5 inch and of the last four 2×0.798 inch."—"Engineering News."

AUTOMATIC BALANCED WHISTLE VALVE.

The whistle valve here shown in section is intended to overcome the disadvantages inherent in the old designs. Under high steam pressures it is difficult to operate the ordinary whistle valves and keep them tight. In them the disk is not balanced, and as they close with the steam pressure the continual pounding on the seat soon causes them to become leaky. The valve here illustrated—made by the Lunkenheimer Company, of Cincinnati—can be operated under the highest steam pressures and can be kept tight without difficulty. The disk is balanced at all times, and when the valve is closing it does not hammer on the seat, but closes firmly and without shock or jar. In opening the steam pressure acts upon the valve disk in such a manner that the disk is raised from its seat almost automatically.



AUTOMATIC BALANCED WHISTLE VALVE.

The steam pressure on top of the disk normally holds it to its seat. A light pull on the lever is sufficient to open the small auxiliary valve. This admits steam through the opening in the center of the stem of the valve to the expansion chamber, where it acts upon the piston the area of which being larger than that of the valve forces it from its seat and allows the steam to pass through the valve. As long as the auxiliary valve is held open the main valve will be kept off its seat and the valve will be open. When the pull on the lever is released the pressure of the steam closes the auxiliary valve,

and the main valve closes easily and without shock, as the steam which is entrapped in the expansion chamber tends to cushion and retard its movement. There is very little wear on the two valve seats, and they can be easily reground by taking off cap at end. These valves are made of gun-metal composition in all sizes from 1 to 3 inches inclusive.—"Iron Age."

TRAIN RESISTANCE.

In view of the limitations which our loading gages fix on the dimensions of our locomotives, the question of resistance of heavy trains at high speeds is a matter of considerable importance. Hitherto it has generally been assumed that the horse power exerted at the tender draw bar varied directly as the weight of the train. Thus consider Clarke's formula, according to which the resistance in pounds per ton $= \frac{S^2}{171} + 8$, where S is the speed in miles per hour. The horse power exerted at the draw bar to haul a 100-ton train at 40 miles per hour on the level would, according to this, be 180, and if the train was doubled in length and weight the power would also be doubled. This latter conclusion would seem, however, to be badly based, and in an article appearing in the current issue of the "Street Railway Journal" the results are given of some 150 experiments made by Mr. John Lundie, on the South Side Elevated Railroad of Chicago, in which the resistance was determined of a number of trains varying in weight from 20 to 100 tons. These figures show a most decided reduction in the coefficient of resistance as the weight is increased. Mr. Lundie's results are well represented by the formula:

$$R = 4\,S\left(0.2 + \frac{14}{35 + T}\right)$$

where R = the resistance in pounds per short ton (2,000 pounds), S the speed in miles per hour, and T the weight hauled in tons of 2,000 pounds. The experiments in question were made by the method adopted by several previous experimenters in which the train is started at a high speed, the power shut off, and observa-

tions taken of the reduction of velocity, after different distances have been traversed. This plan, it will be remembered, was also followed by the committee appointed by the French Government to investigate the increased resistance due to curves.

That the resistance should diminish with the length of the train appears quite rational from the fact that this is partially dependent upon surface friction between the train and the air. In the case of water, Froude found that a varnished board, 2 feet long, showed at a certain speed a resistance of .41 pound per square foot, whilst with a similar board 50 feet long the resistance was but 0.25 pound per square foot. Head resistances being roughly proportional to the cross-section exposed are also proportionately less, the greater the length of the train. Hence generally all air resistances, which at high speeds form an important factor, may be expected to be less per ton hauled the longer the train. The journal and rolling resistances, on the other hand, will vary very nearly directly as the number of axles, and hence, approximately as the tonnage hauled. At low speeds the journal friction is very considerable, but rapidly decreases as the speed of the rubbing surface is increased up 100 feet per minute, being at this latter speed but one-third or so of its value when the speed is 6 feet per minute.

The total resistance of a train is thus made up of: (1) the internal resistances of the locomotive, which from experiments on horizontal engines will probably be 15 to 20 per cent. of the total power to develop; (2) the head resistance, which will be constant in total amount for all lengths of train, and will vary only with the speed; (3) the frictional resistance of the air, which will also increase with the speed, but be proportionately less the longer the train; (4) the journal and rolling friction, which is directly proportional to the number of axles, and diminishes as the speed increases up to a speed of about 14 to 20 miles per hour, and afterwards slowly increases.

Whether it is possible to include in a simple formula the effect of all these variables is perhaps doubtful, and that proposed by Mr. Lundie seems imperfect in form. It does not, however, agree at all badly with Mr. A. Sinclair's experiments on the New York

Central line, and with those of Mr. P. H. Dudley on the same line and on the Philadelphia and Reading Railroad. The figures obtained by these experimenters were as follow:

Observer.	Line.	Speed. Miles per hour.	Weight of train. Tons.	Observed resistance. Pounds per short ton.	Lundie formula. Pounds per short ton.
A. Sinclar	New York Central.....	70	270	19.03	21.1
A. Sinclar	New York Central.....	69.6	270	19.8	21.2
P. H. Dudley....	New York Central.....	51.43	313	16.9	16.35
P. H. Dudley....	Philadelphia and Reading..	60	242.5	18.35	19.0
P. H. Dudley....	Philadelphia and Reading..	63.5	242.5	19.8	19.9
P. H. Dudley....	Philadelphia and Reading..	63.2	213	19.0	20.2

The agreement is, perhaps, as close as can be reasonably expected in a formula of this nature, but on applying it to the results obtained in some recent experiments with very heavy freight trains it appears that the observed resistance was much less than that given by the formula. Thus with a train weighing 940 tons running on the Chicago, Burlington and Quincy Railroad, the resistance on straight, level track was observed to be 5.5 pounds per short ton hauled in place of 8.3 pounds as given by the formula. Again, in a New York Central test, a train weighing 3,428 tons showed a resistance of about 4 pounds per ton when run at a speed of 20 miles an hour. The formula gives about five pounds.—"Engineering."

THE EXTINCTION OF WROUGHT IRON.

With the resistless force of a glacier, but with a rapidity which is only slightly appreciated, steel is now supplanting all forms of wrought iron. Forcible arguments in favor of iron for certain purposes may be made, numerous engineers may continue to specify iron for special classes of work to which they consider it is better fitted than steel, and prejudice may incline the masses of iron workers to prefer the material which can be welded with least

trouble, but the day is near at hand when wrought iron will be an exceedingly scarce commodity. Arguments, preferences and prejudices are equally powerless to stop the advance of the metal which can so much more easily be produced in large quantities than wrought iron. Complaints continue to be heard among mechanics of hard spots in steel which make it of an uncertain character in working, as for instance in threading pipe; of its occasional unsatisfactory behavior in holding a coat of other metal, as in the case of galvanized steel sheets, and of its comparatively rapid oxidation when exposed to the weather or to the action of water. For such reasons a reaction of more or less strength is from time to time noted in favor of wrought iron, but the greater cost of puddled iron as compared with steel silences the complaints, the steel maker sedulously endeavors to turn out a more reliable product and steel continues to preserve its ascendency.

The end of this century, which is now near at hand, will in the estimation of even those who are deeply interested in wrought iron, see the end of wrought iron as a distinctive designation, except, perhaps, in the case of Swedish iron or some other high priced iron specialty. Ordinary bar iron will have completely disappeared from the trade. It is becoming increasingly difficult to secure material from which to manufacture genuine bar iron. Scrap has long been the chief dependence of the bar-iron manufacturer, who is prohibited by its cost from using puddled iron except for those who insist upon having muck bar iron without regard to price. But the great stocks of scrap iron are nearing exhaustion, iron rails are becomng a scarce commodity, and a new supply of cheap material for iron-rolling mills is out of the question. It is almost an impossibility now for an expert scrap dealer to detect the difference between wrought iron and soft steel in the old material offered him, and a guarantee that any lot of wrought scrap contains no steel is out of the question. Busheled scrap for common bar iron may almost safely be said to contain steel to some extent. And so much more steel is now being consumed than wrought iron that the production of steel scrap is increasing at a rate so rapid that wrought scrap will very shortly be principally steel.—"Iron Age."

AN INTERNATIONAL STANDARD FOR METRIC SCREW THREADS.

The question of an international standard of metric screw threads was discussed at a Congress which met for the purpose at Zurich last October, and as a result of their labors a certain standard form of thread and a number of standard diameters for bolts were decided on. The form of thread adopted is based on the Sellars thread, which, it will be remembered, has the shape of an equilateral triangle truncated one-eighth its height at top and bottom. To insure interchangeability, and to reduce the wear on taps and dies, the Congress recommended that the bottom of the thread should be rounded off by any suitable curve, which should not deepen the cut more than an amount equal to one-sixteenth the pitch beyond the standard Sellars type. The apices of the threads, on the contrary, are to be left flat as in the Sellars system. The following standard sizes and pitches were decided on:

Diameter.	Pitch.	Diameter.	Pitch.
Millimeters.	*Millimeters.*	*Millimeters.*	*Millimeters.*
6 and 7	1.0	24 and 27	3.0
8 and 9	1.25	30 and 33	3.5
10 and 11	1.5	36 and 39	4.0
12	1.75	42 and 45	4.5
14 and 16	2.0	48 and 52	5.0
		56 and 60	5.5
18, 20, and 22	2.5	64 and 68	6.0
		72 and 76	6.5

The pitches chosen are, on the whole, somewhat finer than the Whitworth standards, though in the case of the sizes most used —say between $\frac{3}{4}$ inch and $1\frac{1}{2}$ inches—the two systems correspond very closely. This was to be expected, as the standards adopted by Whitworth and Sellars were due to a careful study of the results of many years' experiences. The principal factor in fixing them was the necessity of using threads which could be satisfactorily produced in cast iron. Where wrought iron or steel alone are employed, much finer threads can be substituted with advantage; and thus we find in bicycle work $\frac{1}{4}$-inch bolts with 30 to 26 threads per inch, $\frac{3}{8}$-inch bolts with 26 threads,

and $\frac{9}{16}$-inch bolts with 20 threads per inch, sizes which to a certain extent, are becoming standard in the industry. It has long been a disputed point as to whether the Sellars or Whitworth thread is the better. From a mechanical point of view the sharp corners existing in the former are objectionable, but the form has certainly the advantage of being more easily originated with exactitude. This point had, no doubt, a considerable influence on the decisions of the Zurich Congress, as the threads there chosen will probably be independently produced in a dozen different establishments. Nevertheless the superiority of the Sellars system in this regard has, perhaps, been overestimated since, as a matter of fact, Whitworth bolts and nuts do interchange satisfactorily the world over. Indeed, a 1-inch Sellars' nut will, in practice, fit a Whitworth 1-inch bolt, the toleration allowed in ordinary work being sufficient for this. On the other hand, taps and dies in the Sellars' system wear more rapidly than the Whitworth, the sharp angles being points of weakness. The difference is, however, evidently not a serious one, or we should not have had American bolt and nut makers underselling us in colonial, and, indeed, in home markets, as they did last year.—"Engineering."

POST MORTEM REVELATIONS OF THE KEELY MOTOR.

We quote the "American Machinist" of January 26, 1899, in the following exposé of the "hidden mysteries" of the Keely motor:

We cannot but rejoice at the additional revelations which have been made of the "mysteries" of the Keely motor. These later revelations are the results of an investigation of the building occupied by Keely as a workshop, and in which the exhibitions of his apparatus were made from time to time. The undertaking was instituted by the "Philadelphia Press," and was conducted by a number of eminently competent persons, including the reporters of the newspaper, Prof. Carl Hering, consulting electrical engineer; Prof. Arthur W. Goodspeed, assistant professor of physics of the University of Pennsylvania; Prof. Lightner

Witmer, professor of experimental psychology, of the same institution, and eminent as a student of and authority upon delusions; Dr. M. G. Miller, Coleman Sellers, Jr., and Mr. Clarence B. Moore, son of the late Mrs. Bloomfield Moore, so much of whose money had been absorbed in the Keely schemes.

The facts brought out by the investigations were, after all, only such as could have been easily discovered by less eminent and talented men, if they had been permitted to do so. The building was of a type quite common in Philadelphia. It was a two-story structure, built on a low foundation without cellar, and was 18 feet front and 45 feet deep; the upper story being, however, only 40 feet deep. There were three rooms on the ground floor and two rooms above, with stairway and hall, and an office partitioned off from the front room above. Every particle of the flooring and ceiling was torn out and the walls were closely examined. A lot of trap doors were found in the floors, varying in size from $1 \times 1\frac{1}{2}$ feet to 3×6 feet.

Five of these were in the front room on the ground floor, four in the middle room, and one in the back room, while on the second floor there was a $3\frac{1}{2}$-foot trap door in the center of the front room, a 4×4-foot trap in the center of the back room, and seven small traps distributed about other parts of this floor. Under the floor of the middle room on the ground floor there had been previously discovered a hollow spherical vessel, said to be of steel, weighing three tons and capable of sustaining an internal pressure of 25,000 pounds to the square inch. This vessel was near one of the trap doors and was buried in earth and shop refuse. To put it in the place where it was found, sections of two of the floor beams had been cut away and afterwards replaced. The vessel had a hole in the top tapped for pipe. Four feet away from this, and with an end just within the trap door, was a piece of heavy iron pipe, 14 feet long, with elbows on each end. Under the other trap doors nothing was found but heaps of ashes lately placed there. A false ceiling of wood had been put into one of the upper rooms, with a space of 2 inches between the boards and the timbers where pipes or wires might have been concealed, but none were found there. The floor of the back room up stairs

was somewhat higher than that of the others, and on tearing this up, a piece of small tube, at first thought to be wire, was found running through holes bored in the floor beams. Mr. Sellers had previously found a similar piece of tube built into the partition wall almost opposite to where this was found. This had been put in after the wall was built, as the plaster was different from the orginal. The small tubes found are identical in size and appearance to others which appeared attached to the Keely machine, and which he asserted were merely wires for transmitting the vibratory movements.

This investigation we can scarcely avoid regarding as somewhat of the character of an autopsy. The facts discovered speak for themselves in a way which makes it quite unnecessary for us to offer a word of comment. These things are found after those who are still financially interested in the motor have taken away every portion of the apparatus that was ever visible to the public and much that was never exposed. If an investigation of the entire plant could have been permitted, it seems certain that functional relations could have been traced between the heretofore visible portions and those now for the first time revealed. Why should these things have been concealed? If there are those who can conceive that the concealment was consistent with any honest purpose, we are not to be counted with them, and there never has been a day when we could have been counted with them. While for so long a time the Keely motor, and the performances connected with it, were so prominently and so persistently kept before the public, it came in our way from time to time to speak of the matter, but we have never said anything calculated to foster any hope that there could ever come out of it anything commensurate with the claims advanced, or in fact anything of value to the world. Mr. Keely's ways were not the ways of an honest and truthful man, nor the ways of an inventor or discoverer of anything great, and that he was so long successful in his career is one of the marvels of the age, and all his apparatus is well deserving of a place in some museum where it may stand as a warning to the over credulous, whom, like the poor, we have always with us.

THE KNAPP ROLLER BOAT.

The roller boats do not seem to be having an easy time of it. M. Bazin's, which was to do such great things, was a failure, and Mr. Knapp's, at Toronto, made only six miles an hour. The American inventor, however, tells us that this is the fault of the engines, and he is building a bigger vessel, which will be differently propelled. Experts look on askance, but Mr. Knapp is undismayed, and contributes a description and defense of his boat to "The Marine Review," Cleveland, Ohio, January 12. He says:

"I am satisfied that sufficient power can be applied to get practically unlimited speed, with a light draught, in this type of vessel, with little cost.

"I utilize the forces of nature, which aid me to get speed, while the present type is fighting nature. Consequently I will not need anything like the same amount of power, with vastly greater results. The Frenchman, Bazin, lately deceased, who has been called an eminent engineeer, could not succeed in getting high speed because of another principle involved, which he appears to have ignored, if he was aware of it, viz: the resistance of the water to the forward motion of the plow. His disks being thick at the center and thin at the circumference, always largely submerged, were in effect plows. He only talked of reducing skin friction, and so he would by that mode, but skin friction cuts very little figure at high rates of speed, even at 20 knots.

"The *Campania* takes 30,000 horse power to get 20 knots, while the *St. Louis* takes 20,000 horse power to get 19 knots. It is not skin friction but the resistance to displacement of the water at the bows they must overcome, this resistance increasing as the cube of the velocity at this speed and in an unknown quantity beyond that rate. This type is built with fine lines to get the least possible resistance, but the *Turbinia*, with her 50 horse power per ton of displacement, raised her bow out of the water, and her fine lines were in the air; she could not keep her bow in the water with this great resistance, and therefore she might just as well have been built with a square bow. The *Campania* takes 2½ horse power per ton of displacement, while

my vessel will take about one-ninth of a horse power per ton of displacement, as proved by my experiments at Toronto.

"My theory is that rolling broadside on over the water, I very quickly obtain a resistance which tends to lift my vessel to the surface. As water is incomprehensible [incompressible?] and cannot be displaced quickly, I roll over it instead of through it, and it becomes a granolithic pavement, so to speak, under my vessel, because a body can only displace its own weight in water, and as soon as the resistance exceeds the weight of my vessel, it must practically be rolling on top. Then, like the railroad train running up a grade, it takes less power on the level, and so I get great speed with less power. This is at a light draught of say 12 feet in a diameter of 200 feet.

"I am told, however, by some engineers, who either can not comprehend the principles involved or have not given the subject sufficient consideration, that such a vessel, exposing so great a surface, can never be propelled against a gale of wind, and they instance the *Campania*, drawing 33 feet of water, or say two-thirds of her in the water, while nearly all of my boat is out of the water and exposed to the wind. Now it is not the wind that affects the *Campania*, but the water which strikes her with all its momentum, weighing 64 pounds to the cubic foot, the wave motion having a speed of say 70 feet per second; on the other hand, the wind is striking the one-third of her which is out of the water with a pressure of a few pounds to the square foot.

"Water is 825 times heavier than the air, but the *Campania* goes through it, necessarily at a reduced speed. With my vessel, the resistance of skin friction and the blow of a wave which is much below the center, knocking her legs from under her so to speak, are aids to speed. I turn the enemy into a friend, and am working with nature instead of fighting her. The wind can no more stop my vessel, weighing 17,000 tons and upward, according to her load, than it can a railroad train.

"I may say that I have many broad scientific men and several eminent engineers and naval architects who fully agree with me."

Mr. Knapp proposed to the Government to build a troop ship

for 30,000 men on this principle. Some of the features of this vessel, which would be 800 feet long and 200 feet in diameter, were to be eight decks of varying sizes, each 8 feet 3 inches from floor to ceiling; seven hundred and eighty compartments 62.8 feet long, between the intermediate and outside skins, and 600 more between the intermediate and internal skins; an engine compartment in the middle of the ship, 200 by 168 feet, swung on journals at each end, and cabins swinging in like manner but independently. In the very bottom was to be a tank sufficient to carry enough fresh water to feed the boilers. The coal-bunkers were to have a capacity of 3,000 tons. Uncle Sam has not yet accepted this offer, and indeed he could scarcely be expected to do so. After all, performance is the conclusive test of every promise, and when Mr. Knapp's boat has raced with the *Campania* and beaten her, he may then build vessels by the dozen and ask his own prices.—"Literary Digest."

It appears that the dirigible qualities of this type of steamers in a gale have been relegated to the imagination.—(ED. JOURNAL.)

THE BURSTING OF SMALL CAST-IRON FLY WHEELS.

Mr. C. H. Benjamin has made a series of tests on small cast-iron fly wheels, using models (some 17 in all) of 15 and 24 inches diameter, the models conforming to actual fly wheels made by reputable firms and in practical use.

Wheels 1 to 10 had solid rims, with the exception of No. 5. Wheel No. 11 was a special wheel, but Nos. 12 to 17 had each two joints in the rim, and were 24 inches in diameter. The plan was to test these wheels to destruction, and the speed was obtained from a Don steam turbine with a speed up to 10,000 revolutions per minute. Mr. Benjamin in detailing the experiments drew from them the following conclusions:

1. Fly wheels with solid rims, of the proportions usual among engine builders and having the usual number of arms, have a sufficient factor of safety at a rim speed of 100 feet per second if the iron is of good quality and there are no serious cooling strains.

In such wheels the bending due to centrifugal force is slight, and may safely be disregarded.

2. Rim joints midway between the arms are a serious defect, and reduce the factor of safety very materially. Such joints are as serious mistakes in design as would be a joint in the middle of a girder under a heavy load.

3. Joints made in the ordinary manner, with internal flanges and bolts, are probably the worst that could be devised for this purpose. Under the most favorable circumstances they have only about one-fourth the strength of the solid rim and are particularly weak against bending. In several joints of this character, on large fly wheels, calculation has shown a strength less than one-fifth that of the rim.

It is gratifying to notice the fact that since the subject of joints in fly-wheel rims has been so thoroughly ventilated, several of our prominent engine builders have changed the designs of their wheels by bringing the rim joints opposite the ends of the arms. The experiments, although at times a trifle too exciting, were interesting from first to last. The writer hopes to supplement them by others on models of the more recent rim joints.

The starting point of his design is a hollow rim, which he provides partly to get a greater depth of the rim to provide for greater strength of the sections considered as beams, and partly to get thin sections of metal instead of thick masses, of which the center adds its full quota of weight, but very little strength. The arms he also preferred to make hollow, though he had made some of I-beam section. Each arm was cast with its section and the joints were half way between the arms. The joints were made of shrunk links of the I-pattern, with the special provision that the links varied in length, so that at any one section, the section of the rim should be weakened by the recess for one link head only. Even this weakening, he pointed out, can be largely if not entirely prevented by making the core smaller at the ends where the links are located. In other words, while a solid rim must be weakened at the joint by the metal cut out for the links, a hollow rim may be reinforced at this point by additional metal on the inside, so that the joint shall be substantially as strong as the solid part of

the rim. Another point about which he was very particular was to have his wheels run true—"a wobbling wheel is a dangerous wheel."—"Engineering."

ACCIDENT TO THE MACHINERY OF THE *CINCINNATI*.

On November 18, 1898, while getting under way at Guantanomo, Cuba, the *Cincinnati* met with a serious accident resulting in a fracture across both frames of the port after low-pressure cylinder.

Without dwelling upon the cause of this accident, which as yet has not been sufficiently and fully explained, the rupture having taken place while turning the engines preparatory to reporting ready to get under way, the manner in which repairs were made and by which the ship was enabled to proceed North under her own steam at a fairly good speed was as follows, and is graphically shown in the accompanying illustration:

The inboard guide as well as both after inboard and outboard columns were found to be cracked, and it was necessary to throw out of use the after low-pressure cylinder.

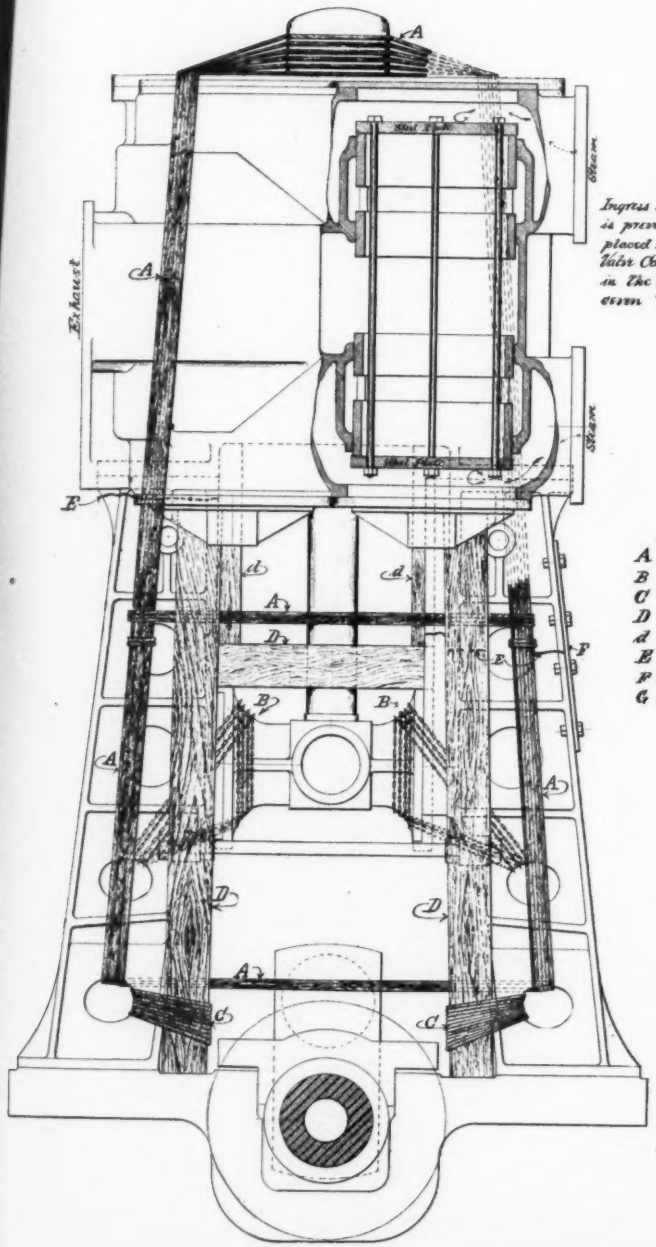
In order to work safely the impared port engine with triple-expansion effect, the following work was done:

1. Taking down connecting rod, valves and valve gear of after low-pressure cylinder.

2. Fitting steel circular plates over the ends of both valve-chest linings so as to prevent the steam from the intermediate cylinder passing directly into the condenser. The upper and lower plates in each valve chest are held in place by seven (7) three-quarter ($\frac{3}{4}$) inch rods uniting them; the pressure from the intermediate cylinder thus assists in making a tight joint. False steel bonnets replaced the upper cast-iron valve-chest bonnets, as the ribs of the old bonnet interfered with the internal plates.

3. Dropping piston to bottom of stroke. Fitting heavy lignum vitæ shores on top of crosshead, and then fitting four (4) vertical beams between these shores and lower cylinder head.

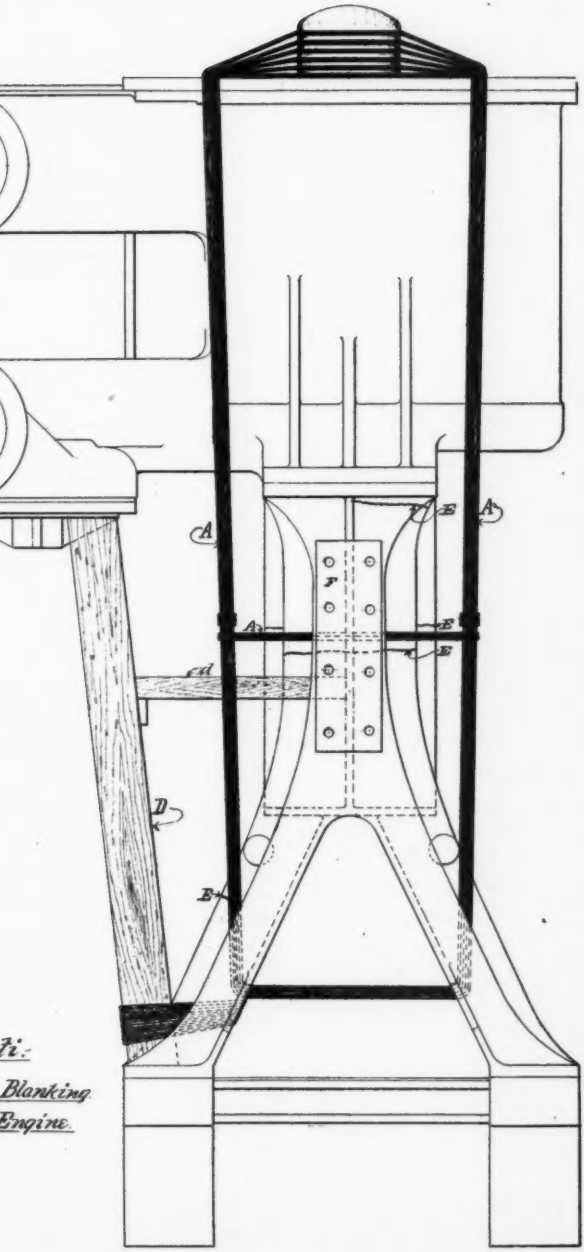
4. The piston was then secured to the lower part of the engine frames by passing small three-eighths ($\frac{3}{8}$) chains over the



Note.
Ingress of Steam to Cylr. is prevented by Steel Plates placed over the ends of Valve Casings and secured in the manner shewn by cross ½" bolts.

Index Letters.
A Wire Rope. 2½" circum.
B Chain. ¾"
C Hemp Rope.
D Shores. 7"x 7"
d Chocks.
E Location of Cracks
F Steel Strap.
G Steel Plates for closing Ports.

U.S.S. Cincinnati.
Manner of Securing & Blanking L.P. Cylinder. Port Engine.



Fi:

Blanking

Engine

upper ribs of the crosshead. The cylinder was thus tied in one way to the unimpaired parts of its sustaining columns.

5. The cylinder was best tied, however, to the frame in this manner:

Through the lowest lightening holes in both columns, and over the after low-pressure cylinder head and around its bonnet, was passed a wire hawser. This hawser was about one hundred and twenty (120) fathoms long and made of two and one-half ($2\frac{1}{2}$) inch rope. The several bights were made taut by chain purchases. The twenty-six (26) vertical parts were then swiftred together with the end of the wire. When completed the parts took up an equal strain, and there seemed absolutely no give to the structure.

6. A steel butt strap five-eighths ($\frac{5}{8}$) inch thick was bolted to the inboard frame, just over the middle and most extensive crack.

7. The overhanging valve chest was shored by two seven by seven (7×7) inch, hard-wood vertical beams, the lower ends resting on the bed plate. The shores were free of the cap. By fitting them into place there was a tendency to prevent any undue strain being thrown on the exhaust pipes. The bases of the shores were lashed to the lowest parts of the frame. The upper ends were recessed into the ribs of the valve-chest bonnets, the bonnets having been turned end for end. Chocks were then fitted between the shore and frame to increase the rigidity.

After the sea trial, a careful examination of the parts comprising the structure was made, and it was not found necessary to take up any slackness, nor to change any detail of the repair.

As the *Cincinnati* has four-cylinder triple-expansion engines, the throwing out of one of the low pressure cylinders still left, three cranks operatable and the running of the engine was, from all reports, excellent.

THE NERNST ELECTRIC LAMP.

The possibility of a most far-reaching revolution in the matter of electric lighting was foreshadowed in a paper read before the Society of Arts, on February 8th, 1899. In this paper Mr. James Swinburne gave an account of the remarkable lamp which

has been devised by Professor Walther Nernst, of Gottingen. This lamp resembles the ordinary glow lamp in that the light is obtained by passing a current through a mass of material of high resistance, which is raised to incandescence by the heat thus generated. In place of a carbon filament, however, Professor Nernst makes use of a rod of magnesia, thoria, or some similar refractory oxide, but the exact nature of the body now used was not disclosed by the lecturer.

At ordinary temperatures such oxides are amongst the best-known non-conductors of electricity; but on heating, like most other non-conductors, their resistance is diminished to an astonishing degree. This property of non-conductors has, of course, been well known for a long time. Indeed, some twenty-three years back, a paper by Professors Ayrton and Perry was contributed to the Proceedings of the Royal Society, in which it was shown that glass, at a temperature of only 100 degrees centigrade, showed quite respectable conducting properties. Such observations, however, led to no practical results till Professor Nernst conceived the idea of constructing incandescent lamps in which the radiating body was one of these ordinarily non-conducting oxides, rendered conducting by highly heating it and then maintaining it at a high temperature by means of an electric current passed through it. The efficiency of such lamps is, it appears, very high, about 1.5 watts being needed per candle-power, whereas the ordinary carbon glow lamps ordinarily supplied take in general about 3.5 watts, so that the saving of current is very substantial. The light emitted is of excellent quality, having none of the greenness to which so many users of the Welsbach gas light so strongly object. The rod requires no protection from the air, in fact it will not, Mr. Swinburn states, work in a vacuum, owing, perhaps, to the fact that the rod is electrolyzed by the passage of the current, and a supply of oxygen is, therefore, needed at the positive terminal to reoxidize the reduced metal. In fact, the whole lamp consists of a rod of the oxide, apparently about $\frac{1}{16}$ inch in diameter by 1 inch long, supported between two platinum terminals.

To start the lamp a Bunsen burner or a spirit lamp is used,

though with the smaller sizes a match will suffice. With one or other of these the rod is heated, and becoming thereby a conductor, the current is able to pass as soon as turned on, when it rapidly raises the whole mass to a very high temperature, at which it gives off a most brilliant light. With the oxides originally used the life of the rod was short, about 40 hours, but now this has been extended to over 500 hours. Mr. Swinburne further showed that a broken rod would, on the fractured surfaces being placed in contact, work practically as well as a whole one. The necessity of starting this simple form of lamp by an extraneous source of heat is, no doubt, in some respects a drawback, and accordingly self-starting lamps have been prepared in which a coil of platinum wire is placed adjacent to the rod. On switching on the lamp the current first passes through this coil, the heat generated being sufficient to raise the rod of oxide to the conducting point, and the lamp accordingly lights up, after which the platinum resistance is automatically cut out. This arrangement would seem to be somewhat expensive; but it has to be borne in mind that when these self-lighting lamps are used, the only part requiring replacement is the oxide rod, and the renewal of this is a simple matter. Since the resistance of the rods diminishes as the temperature increases, it is necessary to add a supplemental resistance to each, if the lamps are to be run in parallel. This resistance is about 10 per cent. of the total, and the energy wasted in it is included in the 1.5 watts per candle-power mentioned above.

One great difficulty in modern incandescent electric-lighting practice is the maintenance of a steady electromotive force at the lamp terminals. Very small variations in this factor make immense differences to the durability of the filament and to the light given. Mr. Swinburne holds out hopes that the Nernst lamp will be much less sensitive to such variations of potential difference, and should these anticipations prove justified, the new lamp will have most excellent prospects of commercial success. The lamps can, moreover, be easily made to run at high pressures, certainly at as much as 500 volts, and, perhaps, Mr. Swinburne states, at as much as 1,000 volts. The rods, which are the

only portion of the lamp requiring renewal are, it is said, exceedingly cheap to make, though this, alas, does not necessarily imply that they will at the outset be supplied at correspondingly low prices. The efficiency of the lamp, it is stated, does not diminish as time goes on.

The discussion which followed the reading of Mr. Swinburne's paper turned mainly on the cause of the efficiency of the Welsbach burner. Mr. Swinburne, in his lecture, had attributed it entirely to the high temperature to which it is exposed, stating that platinum would readily melt when placed close to the mantel. Other speakers were, however, inclined to attribute the efficiency either to selective absorption, whereby radiations of large amplitude are absorbed by the mantle and the energy, afterwards emitted as radiations of shorter wave length, or else to a sort of catalytic action similar to that occurring with platinum sponge, which can be made to glow when a stream of hydrogen is directed on to it. Mr. Swinburne, however, holds strongly to the opinion that the efficiency is solely a matter of temperature. His theory is that most bodies placed in a Bunsen flame fail to take the temperature of the latter owing to their high emissivity. Thoria, on the other hand, has a very low emissivity, and consequently reaches a very high temperature. To increase its light-giving power, about $\frac{4}{1}\frac{}{0}$ per cent. of ceria is incorporated with the thoria. This ingredient has much greater emissivity than the thoria, and being in intimate contact with the latter, reaches about the same temperature. As time goes on, however, the ceria evaporates, so that an old mantle consists of practically pure thoria, and the light falls off accordingly.

The only other point of interest raised in the discussion was of possible anticipations of Professor Nernst's invention. No one contended that any effective claims to priority could be established, but Mr. Campbell Swinton recalled Jablachoff's kaolin lamp, in which light was obtained from a rod of kaolin maintained at incandescence by means of an electric current, whilst Mr. Swinburne himself recalled the Solieil lamp exhibited at the Inventions Exhibition in 1885, in which the light was partially obtained from incandescent lime.—"Engineering."

MACHINE CONSTRUCTION IN AUSTRIA.

In Austria machine construction is making slow but steady progress. Fifty years ago the total output of the Austrian machine shops was valued at 2,000,000 florins; last year it was worth 30,000,000. One great obstacle in the way of the development of the machinery industry in Austria is the lack of specialization. As a general rule, the Austrian manufacturers do not confine themselves to one particular line; many kinds of different machinery are made under the same roof, whereas, as a general rule, the modern machine industry demands, as far as possible, special processes of manufacture in order that the cost of manufacture may be reduced and the possibilities for an extension of foreign trade may be increased. It must, however, be borne in mind that in Austria the general conditions of production, not only for home consumption but for export, are such that manufacture can, as a rule, be carried on only to a small extent relatively. Works turning out special machinery need a good home market and a lively export trade, and for both these conditions Austria is very unfavorably situated. High tariffs and high cost of iron are the main difficulties with which the manufacturer has to contend. To-day, just as it was fifty years ago, the Austrian machine industry aims mainly at supplying the home market and plays no part in international trade. During the last few years the total annual exports of machinery averaged from 3,000,000 to 5,000,000 florins in value, while the importations were of a yearly value of 19,000,000 or 22,000,000 florins.

The Austrian machine builders have at different times petitioned for Governmental interference, but it is very doubtful whether the Government is in a position to exercise any favorable influence upon the industry by any departure from its present attitude. The only thing which possibly, and even then only to a small extent, could affect advantageously this industry is the abolishment or partial reduction of duties, taxes and other fiscal burdens. Besides this favor the manufacturers also demand a revision of the laws dealing with accidents in industrial establishments, a revision of the treaties of commerce, and considerable reductions in the railway and water freight rates. An

agitation for the abolition of the iron trusts is also being very vigorously conducted. But, in spite of all these unfavorable surroundings, the last fifty years has seen a wonderful progress in this industry. In 1848 there were in Vienna and lower Austria sixteen machine works employing some 2,400 hands; in Bohemia, ten works with 1,000 workmen. Besides these there were, perhaps, five works with some hundred men. Of these only five or six were of any importance, while the other ones were more in the nature of repair than machine shops. In Vienna there were two locomotive works—those of the American, Norris, and those of Specker, which afterward went into the hands of the Kaiser Ferdinand Railway Company.

To-day there are, without counting numerous small workshops, some one hundred and sixty machine shops in Austria, giving employment to about 25,000 hands, and in which a capital of at least 70,000,000 florins is invested. All the locomotive works are joint stock companies; the oldest is that of G. Sigl, in Neustadt, near Vienna (Wiener-Neustadt). These works represent a capital of 1,960,000 florins, and turned out in 1896 sixty-nine locomotives and forty-eight tenders, valued at 2,100,000 florins, besides steam engines, boilers, etc., valued at 690,000 florins. The Wiener Locomotivsfabrik Actiengesellschaft in Wien-Floridsdorf have about the same capacity and represent about 1,620,000 florins capital. Their output in 1896 was valued at 2,400,000 florins and comprise seventy-one locomotives and thirty-three tenders. In the same year the Government locomotive works turned out a value of 2,600,000 florins. The total output of all Austrian locomotive works comprised in 1896 two hundred and sixteen locomotives, and one hundred and twenty-eight tenders, besides other machinery and parts to the value of 1,120,000 florins. The workmen employed in all locomotive works numbered about 3,500. During many years the Austrian locomotive works built many engines for foreign countries, such as Russia, Roumania, Italy and Spain, and even France.

To-day the machine industry in Bohemia and Moravia is also of great importance. Of late years a number of large works have been established in these countries. They build steam engines,

boilers, brewery, distillery, sugar and texile machinery. The large works of the Maschinenbau Actiengesellschaft, vormals Breitfeld Danek & Co., in Prague, filled orders to the value of 3,300,000 florins in 1896. Other very important works are the Prager Maschinenbau A. G., vormals Ruston & Co., and the works of F. Ringhoffer at Prague. The Erste Brünner Maschinenfabriks Gesellschaft executed orders (1896–97) to the value of 1,756,000 florins, turning out seventy-three steam engines, eighty-seven boilers, etc. Many other important works in Bohemia and Moravia were running on full time during the past year. A high rank among the Austrian machine works is occupied by the Stabilimento Tecnico Triestino at Trieste, founded in 1856, and working with a capital of 3,000,000 florins.

Machine tools are not made to such an extent as to meet the requirements of the market. The principal Austrian makers are F. Reitbauer, Ernest Dania & Co. and Hoerde & Co., all of Vienna.

There is no doubt that with proper efforts our exports to Austria could largely be increased. In 1897 the importation of machine tools amounted to a value of about 950,000 florins. Large quantities of machine tools are still imported from Germany and Great Britain, although there is scarcely a machine shop in Austria in which American tools, however few, cannot be found. By far the greater part of the machinery imports consist of textile machinery (4,800,000 florins in 1897, of which 2,100,000 cotton machinery), which is almost entirely of English origin. Sewing machines were imported to the value of 1,200,000 florins, or about $504,000, to which we contributed only $7,853. Agricultural machinery was imported to the value of about 1,000,000 florins ($420,000), and even in this item our share was very unimportant, our total exports of agricultural machinery to Austria amounting in 1897 to $13,699. Portable engines were imported to the value of 800,000 florins ($336,000), to which the United States contributed scarcely anything. The imports of electro-dynamic machinery, which came chiefly from Germany and Switzerland, were valued at 780,000 florins.

A considerable loss to the Austrian machine industry has arisen through the development of the Hungarian machine industry.

And up till now it has been impossible for the Austrians to discover a new outlet which could compensate them for the loss of the Hungarian market. As a consequence, the works are more and more being established in the country instead of in the large towns, country labor being found much cheaper and the means of transportation adequate. Of late quite a number of old established works have been removed from the cities to the country. What the coming years will bring can scarcely be said. The fact remains, however, that Austria should be closely observed by Americans, with a view to seizing every opportunity which may present itself.—"Iron Age."

ADVANTAGES OF MECHANICAL DRAFT OVER CHIMNEYS FOR BOILER FURNACES.

Mr. Walter B. Snow, at the recent meeting of the Northwestern Electric Association, strongly advocated the substitution of mechanical draft in place of chimney draft for furnaces. This can be accomplished either (1) by forcing the air into a closed ash pit, and maintaining therein a pressure in excess of the atmosphere; or (2) by exhausting the air and gases from the flue or uptake, and thereby creating a partial vacuum which will cause a constant onward flow of air to the combustion chamber. The first method is designated as "forced draft" and the latter as "induced draft." In both types of mechanical draft centrifugal fans are used to render the draft conditions positive at all times.

The advantages of mechanical draft as stated by the author are its positiveness and flexibility. Its positive character renders its action independent of the weather; and its flexibility lends to it that characteristic so lacking in the chimney, the capability of exactly adapting the intensity of the draft as well as the volume of air to the requirements of the instant. Especially is this advantage noteworthy in cases where the service is irregular in character, that is, when the demand for steam is fluctuating, as, for example, in traction service where they are often sudden and immense.

Again, a convenient feature of mechanical draft, pointed out

by the author, consists in the ability to burn cheap fuels, which are almost invariably of small size and require an intensity of draft which is not readily created by means of a chimney.

Also, the positiveness and intensity of the draft produced by a fan makes it a valuable aid in connection with the suppression of smoke—a question that is of the first importance in cities where soft coal is the only fuel used.

Turning to the economic side of the question, the author points out that the chimney is an absurdly inefficient means of creating an air movement, affirming that it can readily be shown that under the ordinary conditions of steam-boiler practice a fan will remove a given amount of air with the expenditure of only one seventy-fifth of the cost required by the chimney. Other economic advantages are itemized, but need not be specially referred to. The concluding portion of the paper contains a valuable statement of the comparative cost of the two systems, which should receive the careful attention of steam users. This is accordingly quoted:

"In order that a definite comparison may be made between the two methods of draft production, a certain 1,600-horse-power plant has been taken, of which the cost is known. This consists of eight modern water-tube boilers, two economizers, and a chimney 8 feet in diameter by 180 feet high. The latter is located just outside the boiler-house wall. If a duplex induced mechanical-draft apparatus, each fan capable of operating the entire plant, should be substituted for the chimney, it could be placed immediately above the economizers, and with its attached engines could be rigidly supported by beams resting on the economizer walls. A short stack would serve to discharge the gases above the roof.

"The cost of the chimney, with damper regulator and dampers, is $9,300; that of the fans, engines, draft regulation and short stack, installed complete, would be about $3,500, or only 38 per cent. of the draft-producing apparatus for which it is substituted. That is, the saving would be $5,800.

"With the increased draft produced by the fans it would be possible to raise the combustion rate and the steaming capacity, or, what is equivalent, the same capacity might be maintained

with a less number of boilers. Suppose one of the eight boilers be omitted from the original design, making the plant 1,400 nominal horse power. A further saving of about $4,000 may thus be secured.

"If the land be valuable the reduction of space incident to the employment of mechanical draft may have an appreciable effect. If worth, say, $2 per square foot, the saving by omission of chimney and one boiler would be about $2,000. The total saving in first cost resulting from an expenditure of $3,500 for mechanical draft may thus be shown to be $11,800; that is, the saving is nearly three and one-half times the expenditure necessary to secure it. Obviously there is a coincident reduction in the fixed charges for interest and taxes.

"The power expenditure for operating the fans should not be practically appreciable in any well-designed plant in which provision is made to utilize the exhaust steam from the fan engine.

"The most direct saving in operating expense which may be secured by the introduction of mechanical draft is that resulting from the utilization of cheaper fuel. Such a plant as previously described would, under good conditions, probably require at least 8,000 tons of high-grade coal per year, operating ten hours per day. If a saving of only 25 cents per ton could be effected it would represent an aggregate of $2,000 per year, a very good return on an investment of $3,500. But in many cases much greater savings may be brought about. A case in point is that of the United States Cotton Company, Central Falls, R. I., where, with a 1,000-horse-power boiler plant, the fuel originally employed with chimney draft was George's Creek, Cumberland, costing (at that time) $4 per ton. With forced draft a mixture of No. 2 buckwheat screenings and Cumberland is now used, costing $2.62 per ton. The saving has been about $125 per week, enough to pay for the special steam fan in about six weeks.

"Other direct and indirect advantages of mechanical draft might be presented, but the limits of the paper will not permit. If it were not for its rough-and-ready character, the chimney would long ago have been discarded, because of its wastefulness. In the search for the highest efficiency such waste can no longer be

ignored, and when dollars and cents are concerned, crude methods must give way to those of greater refinement. It is for this reason that the most progressive engineers of the present day are not only considering but adopting mechanical draft as a substitute for the chimney."—Franklin Institute.

MISCELLANEOUS.

MANUFACTURE OF STEEL CASTINGS IN THE UNITED STATES.—Mr. Stewart Johnston read an instructive paper on this subject at the recent meeting of the American Foundrymen's Association. After giving a historical sketch of the growth and development of this branch of the metallurgic arts in the United States, and some useful hints respecting the difficulties encountered in practice and how to overcome them, he gives the following statement of the present state of the art:

"The uses to which steel castings are put are beyond enumeration, and are daily becoming more varied, although at the time of their introduction in the United States, in the seventies, their position in the commercial world was one of insignificance. Limited to a few lines, the production in first years did not annually exceed 200 tons. Steel castings now invade every field in metallurgy save the one occupied by the chilled-iron roll when used for rolling finished steel, and for that purpose no steel cast substitute has ever been considered a dangerous rival. It is estimated that the annual production of steel castings in the United States is from 80,000 to 100,000 tons."

WATER FOR BOILER USE.—The "Broad Arrow" of December 31st notes that the Admiralty have forbidden the use of shore water in boilers of torpedo boats, claiming that air and foreign deposits were carried in this water to the great detriment of the boilers and the clogging of the tubes. Distilled water from their own evaporators is to be used exclusively.

This matter of using shore water has always been avoided as far as possible in our Navy, but probably through the fact that fire-tube boilers we have found the deposits resulting from this

use to be so slight compared with the occasional salting which occurs by the sometimes unavoidable use of sea water, that the attention of our own officers to the possibilities of ruining small water tubes by using shore water has not been made sufficiently important.

There can be no question as to the importance of restricting the quality of water used in torpedo-boat boilers to that produced by evaporators, and our own Government has taken the matter up of increasing the evaporating plant on these boats as well as of our ships, in order to so limit it.

THE FUTURE OF ACETYLENE AS AN ILLUMINATING AGENT.—In a thoughtful editorial on this subject, the "Electrical World" advances the following views upon the role which acetylene may be expected to play as an illuminant in competition with gas and electricity:

"As a competitor in the illuminating field acetylene will probably be a greater rival of illuminating gas than of electric current, and it is possible that its success will be of more benefit than harm to the latter. It is the old story over again of one rival stimulating another in competition, and by means of improved service and reduced cost increasing the demand by an amount greater than its own supply. Illuminating gas, electric lighting and acetylene all have their own individual advantages which, to a certain extent, outline certain fields of application of each in which the others cannot compete. For vehicle lighting, including train lighting, and for gas distribution where but a small percentage is used for fuel, acetylene will probably show advantages over other forms of gas; while for combined heating and lighting service from one system, illuminating gas cannot be met by either acetylene or electric current, but for isolated plant service, theater lighting and all cases where ease of control from a distance or convenience of ignition or adaptability to special decorative effects are of any importance, the electric current has the advantage. It cannot be met by its competitors in the qualities of safety, neatness, cleanliness, convenience and elegance."—Franklin Institute.

NEW METHOD OF WATERPROOFING PAPER.—The German journal "Neueste Erfindungen," describes the following method of making a water-proof paper: The sheet is coated on both sides with a solution consisting of one part gelatine, four parts water and one part glycerine. When dry, the paper is immersed in a 10 per cent. solution of formalin. After this treatment, the paper is said to become impervious even to steam.

IRON-NICKEL ALLOY FOR INCANDESCENT ELECTRIC LAMPS.—The so-called leading-in wires for attaching the carbon filament and making electric connections have thus far been made of platinum. This appears to be the only metal which has the same rate of expansion and contraction as glass, and its use for this purpose has consequently been compulsory with the manufacturers of electric incandescent lamps, since by no other means has it been found possible to avoid leakage of air into the interior of the bulb and the speedy destruction of the filament.

From experiments lately conducted at one of the Reichanstalten in Germany, on nickel-iron alloys, it has been developed that the coefficient of expansion of such alloys varies according to the percentages of the two metals present. Furthermore, it is said to have been experimentally demonstrated that an alloy of iron and nickel containing 45 per cent. of nickel possesses the same rate of expansion as platinum, and it is proposed to use this alloy to replace platinum in the manufacture of incandescent electric lamps.—Franklin Institute.

ARMOR TESTS.—At Ridsdale, the proving ground of Messrs. Sir W. G. Armstrong, Whitworth & Co., Limited, a trial took place recently of a plate representing the armor of the Japanese battleship *Asahi* now building on the Clyde by the Clydebank Enginering and Shipbuilding Company, Limited. The makers of the armor are Messrs. John Brown & Co., Limited, of Sheffield, and the trial plate, 8 feet by 8 feet 8.8 inches thick, was cut from a partially finished belt plate selected by the Japanese authorities from among those in course of manufacture. The attack consisted of three blows from 8-inch armor-piercing shot

of 250 pounds weight, made for the Japanese Government by Messrs. Armstrong, on the Wheeler-Stirling process. The striking velocities of the three rounds were respectively 1,859, 1,964 and 2,039 foot-seconds, and all the shots were smashed to pieces without indenting the plate beyond an estimated depth of 3 inches. Except for a few very fine hair-cracks in the face, and the usual splintering of the surface round the point of impact, no other damage was apparent. On later examination the back was found intact except for three slight bulges, of which the most prominent did not exceed $1\frac{1}{2}$ inches in height.

ANOTHER NEW ELEMENT.—The discovery of a new element, which has been named polonium, is announced in a recent communication by M. and Madame Curie to the Paris Académie des Sciences. The reasoning which led the discoverers to suspect the existence of this new body is of interest. Some time back M. H. Becquerel drew attention to the fact that the salts of uranium had the property of emitting a radiation having properties very similar to the X-rays. Thus they would impress a photographic plate, traverse materials opaque to ordinary light, and, further, make the air through which they passed a conductor of electricity. Further researches showed that uranium was not alone in emitting these radiations, as thorium and its compounds enjoy a similar property. Madame Curie further noted that certain specimens of pitch-blende showed the property even more powerfully than uranium itself, and was thus led to suspect the presence of a new element. By an elaborate chemical investigation, M. and Madame Curie have now succeeded in isolating this body in the form of a sulphide. From a chemical point of view, the new element resembles bismuth, but its radiating powers are said to be 400 times those of uranium.—"Engineering."

THE QUESTION of the porosity of thin steel plates under heavy hydraulic pressure having been raised, experiments have been carried out at the Washington Navy Yard with the view of settling the point in a practical way. Pieces of sheet steel of $\frac{1}{4}$ inch, $\frac{1}{8}$ inch, $\frac{1}{16}$ inch and $\frac{1}{32}$ inch in thickness were subjected to a

water pressure of 6,000 pounds per square inch, and in no case was any percolation found. A $\frac{3}{8}$-inch rivet joining two $\frac{1}{8}$-inch plates also proved tight under the same pressure. A test was also made to determine the friction of water under high pressure, and, while it was inconclusive, there was no evidence that the friction of water under high pressure was any greater than the friction of water not under pressure.—"Engineering."

ELECTRICAL VEHICLES IN THE RECENT STORM.—The severe snowstorm in New York city on November 26th last, gave the first opportunity for observing the behavior under trying climatic conditions of the cabs and broughams operated by the Electric Vehicle Company. To the surprise of even some of their most staunch upholders, the electric automobiles gave better service than did horse-drawn vehicles. The cabs ran through the whole night, the last coming in about 6 o'clock in the morning, by which time the snow had reached an average depth of about 8 inches, and much more where drifted. Other cab companies turned over orders to the electric service rather than fill them themselves. No very marked change in their running was noticed, although the mileage per charge of battery was, as a precautionary measure, greatly reduced, the vehicles being ordered in for fresh charges after covering ten or twelve miles. The ease with which they ran is probably due to the large pneumatic tires, 5 inches in diameter, with which they are fitted, which give a large bearing surface and reduce the tendency to cut deeply into the snow.

THE WEAKEST LINK IN THE CHAIN.—The electric motor directly coupled or geared to its load, with no intermediate mechanism which can slip, as can a belt, becomes, especially with high-gear ratios, a source of great possible strains. Unlike the steam engine and other sources of mechanical power, its maximum torque is, as a rule, a great many times that of its normal load, and, especially in the case of shunt-wound motors, any obstruction to the movement of the load tending to reduce the speed causes an instantaneous application of the great force available.

Especially is this the case with motors driving such loads as cranes, elevators, etc., where the speed reduction is considerable and worm gears are commonly used. A recent disaster that was probably in part due to this very cause is the fatal accident which occurred recently in an electrically-driven elevator in New York city. Here it appears that the car came down with full speed against the bumpers and the motor continued working, lifting the counterweights after the car had struck, in spite of the greatly increased load, until the counterweights struck at the top of the shaft, throwing some of them out of the frames, whence they fell and smashed through the car with fatal results. In other instances motors have torn the cables loose from elevator drums, cars, or counterweights, broken the wheel spiders or stripped the gears.

In cases of this kind the weakest point of the system will, of course, yield first to the strain, and, very fortunately, the weakest point can be readily made a part of the electrical circuit, the breakage of which causes no damage whatever. The action of fuses is too slow for such sudden loads as are liable to be imposed on rigidly-coupled machinery, so that circuit breakers should always be installed. Unfortunately the circuit breaker, like the safety valve of early boiler installations, is very readily overweighted or tied in, and one that, like most modern types of safety valves, could not be tampered with would be a blessing for such service. With a breaker that could be absolutely depended upon the maximum strain, outside of the inertia effect of fly wheels, etc., could be exactly calculated and allowed for. In most of such loads, among them cranes, elevators, etc., there is no great amount of stored kinetic energy, and where this is necessary, as in printing-press service, etc., other safeguards might be provided if necessary.—"Electrical World."

THE X-RAYS IN METALLOGRAPHY.—The latest application of the X-rays is to the study of metallic alloys. When the alloy is composed of two metals having different transparencies to the rays, radiographs taken of thin plates show the separation of the two during solidification. As an example, it is stated that

an alloy of aluminum and gold shows on solidification the segregation of a definite compound of the two metals, which separates in well-defined crystals.

THE STEAMSHIP *St. Paul*, of the American Line, which had been overdue since January 7, arrived in New York on January 10, after a trip of 9 days, 20 hours and 16 minutes, the slowest run ever made by her. The delay was due to a crack in an elbow of the 16-inch main steam pipe leading to the starboard engine, which made it necessary to reduce the steam pressure to 100 pounds. As soon as the crack was discovered, without shutting down the engines, two heavy clamps were placed about the pipe and screwed up until the opening was practically closed. The injured section was then wound with ½-inch copper wire. The whole operation requiring about one and one-quarter hours. The accident was discovered when about 800 miles from The Needles, and the remainder of the voyage was made at a speed of about 13 knots, although this was reduced at times by the heavy head seas.—"Engineering News."

THE TAPER OF PIPE THREADS.—The pipe tap should have a greater taper than the threading die. Just how much greater may be a matter of choice, but one inch taper to the foot for the tap and three-quarters for the die is good enough in practice and avoids all necessity for stuffing boxes, red paint or other dope. The reason is easy to see. If the pipe has the less taper the joint makes up at the end of the pipe first, as it should do, and that point being tight all the rest must be tight too. With moderate screwing up the pipe end becomes smaller and is ready to expand with the pressure, while the fitting becoming larger is already under tension to prevent further expansion. With a difference of one-quarter of an inch in the tapers a hydraulic pipe will readily fit the whole distance the thread is screwed in. The joints so made are good for pressures up to 10,000 pounds and can be taken apart and put together indefinitely. Oil that is good enough for the die is good enough for the joint, and no dope is of any value.—Correspondent in "American Machinist."

SHIPS.

UNITED STATES.

Missouri.—Decision has been reached regarding the boiler plant of this vessel, which is that the arrangement will include twelve Thornycroft boilers placed in four separate water-tight compartments, each compartment being 48 feet long and 20 feet 6 inches wide. Thus three boilers will be in each compartment, two back to back, near the middle of the compartment, and one with its back to the center athwartship bulkhead. This gives an end single fire room 8 feet 6 inches long, and a middle double fire room 12 feet long in each compartment. The boilers are to have a total tube-heating surface of about 60,000 square feet, and a total grate surface of about 1,000 square feet. Details of the hull arrangements will be very similar to the *Maine's*, but this, together with the details of the *Ohio's* hull, will be published as soon as finally settled.

Ohio.—The arrangement for the *Ohio's* boilers will probably be similar to that of the *Missouri*, although at this writing the question has not been absolutely settled.

Wisconsin.—This first-class battleship was launched at San Francisco on Saturday, the 26th of January, 1899. She will carry four 13-inch guns and fourteen 6-inch quick-firing guns. She has a displacement of 12,325 tons, and a speed of 16½ knots. Her coal capacity is 1,500 tons. Description of this vessel was given on page 797, volume viii, of the JOURNAL.

Farragut.—On December 2, 1898, after verifying weights and distribution of same, and getting draughts as follows: forward, 4 feet 9⅛ inches; aft, 8 feet 2¼ inches; mean, 6 feet 5 1/16 inches; displacement, 236.3, a successful one-hour run of the *Farragut* for her final speed trials was made over a measured mile in San Francisco waters. The first part of the run began at 10·28·55 A. M., and ended at 10·56·55 A. M., or 28 minutes, and the second part of the run began at 11·02·00 A. M., and ended at 11·34·00 A. M., or 32 minutes, making a trial of 60 minutes, or one hour's

run as required. The interval of time consumed in turning between the first and second parts of the run as recorded by the Board was 5 minutes and .05 seconds.

During the runs the recording of the counters were taken with the following results:

No.	Interval.	Starboard.		Port.		
1	7½ minutes,	442.53		425.33		
1	7½ minutes,	442.53		425.33		
2	7½ minutes,	436.26	*A*	423.20	*B*	
3	7½ minutes,	433.20		422.40		
4	5½ minutes,	426.99		411.27		419.3
5	8 minutes,	422.62		412.00		
6	8 minutes,	440.75	*C*	429.25	*D*	
7	8 minutes,	311.75		423.00		
8	8 minutes,	432.75		419.87		

The maximum revolutions observed during the run was, starboard engine, 452; port engine, 432; mean, 442, or a speed of 31.4 knots.

The Board was of the opinion that the counter which marks thousands failed to record once during the seventh interval, thereby making the revolutions for that interval 1,000 less than they should be—that is, instead of a mean of 311.75 for the seventh interval, it should be 436.75, making the total mean for the hour of 427.65 instead of the official number of revolutions reported, 419.3. This would give a speed of 30.62 instead of the official speed of 30.13.

Observations were made to determine the change of trim of the vessel at different speeds, as follows: At 30 knots, the change of trim was 45 inches; at 28 knots, 36 inches; at 26 knots, 33 inches; at 20 knots, 9 inches.

The change of trim varied somewhat with the depth of water over the course.

There was no apparent following-wave astern, but large swells travel with the ship at right angles to the course about 50 feet outside the wake. The swells increased in height and length as the depth of water decreased.

The Board took into consideration the depth of water over the measured course, which varies from 6½ to 15 fathoms. It was found that at speeds of over 24 knots the increase in vibrations and pounding of the propellers in the shoal water was such as to produce a dangerous increase of friction on bearings and strain on the hull in turning, of such a nature that the Board therefore limited the speed in turning to 23 or 24 knots, without shutting off the steam.

Patent logs could not be used to verify the runs on account of the turning necessary on the measured-mile course and the turn during the hour's run.

At low speed very little vibration was observed, but at speeds above 20 knots the vibrations at certain points became excessive, and, as a result, stiffening angles were fitted underneath the main deck just forward of the wardroom hatch, and also four-pound plates just abaft the, propellers were removed and six-pound plates put in, and four stiffening angles extending from frame No. 110 aft were fitted on the outside of the bottom plating. The vibration was maximum at a speed from 20 to 22 knots.

Mackenzie.—The final acceptance trial of this boat was made on December 12, 1898, in the Delaware River.

The weights carried on this trial were as follows:

Articles of load.	Weights required to be carried.	Actual on board.	Additional weights carried to compensate for difference.	
	Pounds.	*Pounds.*		*Pounds.*
Equipment....	8,960	1,978	8 officers	1,200
			24 men	3,600
			Coal in bunkers (extra)	2,182
Ordnance.....	7,840	1,338	Coal in bunkers (extra)	6,502
Coal.....	11,200	11,321	.....	
Total.....	28,000	14,637		13,484

The corresponding draught of the vessel before and after the two-hour run was:

	Before.	After.
Forward,	4 feet 5 inches.	4 feet 3 inches.
Aft,	5 feet 2 inches.	5 feet 0 inches.
Mean,	4 feet 9½ inches.	4 feet 7½ inches.

The weather was favorable for the trial, there being no wind at first, and only light airs from the southward the latter part of the time. The sky was overcast with occasional light falls of snow. The tide was at high water when the two-hour trial was begun, but soon after the ebb tide made and continued during the run.

The *Mackenzie* left Chester at 9·45 A. M., and, with the members and assistants of the Board, proceeded down the Delaware River. At 10·23 A. M., the vessel, being then below Wilmington, and a short distance above Deep Water Point, the two-hour full-speed trial was begun. During the trial the speed of the vessel was checked by careful observations of known positions on shore, and, allowance being made for the force of the tide, it was evident that the required speed was being obtained. The run was to some four miles below Bombay Hook Light in Delaware Bay, where the turn was made, and the vessel headed again to the northward. An extremely good opportunity of verifying the speed was obtained in twice passing over the distance between Reedy Island Light and Bombay Hook Light, these two runs having been made so near together as to render it probable that no change in force of tidal current had occurred, so that therefore, the tide having been favorable in heading to the southward and contrary in heading to the northward, the force of current could be considered as eliminated in the mean speed. The result agreed most satisfactorily with the speed taken from the standard curve as corresponding to the number of revolutions. The times of passing the various known points on shore, as marked by a chronometer (G. M. T.), was as follows:

	h.	m.	s.
Start above Deep Water Point,	4	53	30
Transit, first range, measured mile,	4	55	27
Transit, second range, measured mile,	4	58	11
Fort Delaware and Finns Point,	5	19	30
Reedy Island Light,	5	36	00
Bombay Hook Light,	5	59	00
Turn,	6	05	00
Bombay Hook Light,	6	15	00
Reedy Island Light,	6	42	00
End of trial,	6	53	30

The average number of revolutions for the entire two hours was three hundred and ninety-one and one-tenth (391.1), corresponding to which the standard curve gives a speed of twenty and eleven hundredths (20.11) knots per hour, or eleven hundredths of a knot over the speed required by the contract.

The steering gear was tested at full speed and worked very satisfactorily. The helm was put hard a-starboard in ten (10) seconds, then to hard a-port in sixteen (16) seconds, then to amidships again in ten (10) seconds, the helm moving readily and the boat responding quickly to the motion of the rudder. With an initial list of 4 degrees to port, which the vessel seemed to take up at full speed, the heeling was, helm hard a-starboard, 9 degrees, hard a-port, 2 degrees.

The forward steering gear was thrown out and the after gear and steering wheel connected in four minutes.

The steering gear worked easily, and was very simple in its mechanism. The Board approved heartily of the absence of steam-stearing gear in so small a torpedo boat.

The *Mackenzie's* seagoing qualities, so far as could be judged, were good, and the vibration was no greater than in other torpedo boats under similar conditions of speed. The engines worked very quietly, and the blowers made less noise than in other boats. An approximation of change of trim at the highest speed showed about $5\frac{11}{100}$ feet in length of vessel.

The bow wave of the *Mackenzie* is rather prominent, but in deep water the stern wave is not large; the latter increases rapidly, however, as the water is shoaled.

During the two-hour full-power speed trial the steam pressure was at no time in excess of the maximum working pressure, 250 pounds above the atmosphere, and there was no foaming of the boilers. The throttle valve of the main engine was kept wide open, and was not even partially shut off at any time during the trial. The machinery, both main and auxiliary, functioned very satisfactorily, with the exception of the air pump, whose after piston rod worked loose, becoming unscrewed from its crosshead. There was little vibration in engine frames, and no heating of journals, and no water was used on the engine, ex-

cept what circulated through the cross head guides. Upon both trials the forward revolution counter broke down and could not be repaired on board. On the occasion of the second, and successful, trial a much more regular pressure of steam was maintained, due to better work on the part of the fire-room force.

The full results of the trial are contained in the report of the engineer member of the Board and the mean results are given in the following statement:

Maximum revolutions,	398.53
Average revolutions,	391.1
Maximum steam pressure at engine, pounds,	248.
Average steam pressure at engine, pounds,	236.2
Maximum air pressure in fire room, inches,	4.75
Average air pressure in fire room, inches,	3.4
Maximum vacuum, inches,	26.
Average vacuum, inches,	24.5
Minimum vacuum, inches,	23.
Speed for the two-hour trial, knots,	20.11
Revolutions corresponding,	391.1

The weight of machinery as far as completed, including water in boiler, condenser, pipes, tanks, etc., is $26\frac{288}{2240}$ tons.

Davis.—The official trial of this boat was made on November 24th, and was successfully continued for the two hours required in the contract without any undue friction of engines or excessive vibration of hull, all parts of machinery and steering gear working smoothly to the end, in so much that the required speed could have been maintained for a further period, in evidence of the good workmanship, adjustments and further endurance of vessels of this class.

The amount of coal to be carried in beginning of trial trip (19,764 pounds) was based upon observed coal consumption, and calculated to insure an average of at least six tons during the two hours' run. Actual results were as follows: Coal on board at beginning of trial, 19,764 pounds; at end of trial, 11,504 pounds; burnt on trial, about 8,250 pounds. Average load of

coal carried during trial, 15,634 pounds, about 7 tons. A surplus of coal to the credit of the contractors.

The vessel in addition was ballasted, as required by contract, to compensate for unfinished items, etc.

Under these conditions, her observed draught was as follows: Forward, 4 feet $5\frac{1}{2}$ inches; aft, 6 feet $1\frac{3}{4}$ inches; mean, 5 feet $3\frac{5}{8}$ inches; displacement, 126 tons.

The vessel, loaded as described above, proceeded to the free route selected, in the Columbia River, about 12 miles from Astoria, and after some preliminary steaming the official run was begun by signal at 12·13 P. M., and successfully finished at 2·13 P. M. The engines averaged 382 revolutions per minute (23.41 knots). The estimated speed is calculated from the revolutions and official slip of $16\frac{2}{3}$ per cent. No patent logs could be used, owing to the continual change of course in following the deepest channel of the river.

The maneuvering qualities of the vessel were satisfactory, as was evidenced by numerous turnings at different speeds. There was no excessive vibration at maximum speed. The maximum vibration occurs just forward and abaft the engine hatches. This is due to the engines being tied to girders under the deck terminating at these points.

Observations made to determine the squat of the vessel relative to the horizon gave results corresponding to previous Board's report, namely: at 382 revolutions, $1\frac{1}{2}$ degrees; at 410 revolutions, $1\frac{5}{8}$ degrees. The average squat relative to the surface of the water aft was $5\frac{1}{2}$ inches at 382 revolutions, and $7\frac{1}{2}$ inches at 410 revolutions. These conditions are based upon a constant depth of water. The squat varied with varying depths of water on the course.

CHINA.

Torpedo-Boat Destroyers for China.—These vessels, built by Mr. F. Schichau, of Elbing, for the Imperial Chinese Navy, with their trial load, complete outfit and armament, and with 25 tons of coal on board, are reported by Mr. Schichau to have steamed 35.2 knots over the measured course of $18\frac{1}{2}$ sea miles, and with 67 tons of coal (*i. e.* full bunkers), 33.6 knots. The

trials, Mr. Schichau writes, took place in free, open sea, between the Lighthouse Tower at Pillau and that at Brüsterort. During the trial trips the weather was sometimes very windy, and on some trials was even of force 5. This force of wind, however, did not prejudicially affect the speed. The distance between the two lights is 18½ sea miles, and the course was steered by the compass. This course, he states, was covered in 32 minutes 30 seconds, and on one occasion even in 31 minutes 15 seconds. The maximum speed mentioned is 36.7 knots, but it is not stated whether the 35.2 knots, already indicated, is the mean of the runs over the course. All the four torpedo-boat destroyers are said to have made this speed easily, without any effort and without hard work on the part of the stokers. The air pressure was 40 to 45 millimeters, equal to 1.58 inches to 1.77 inches on the water gage. The contract speed was 32 knots. With natural draft the boats made between 30 and 31 knots with 67 tons of coal on board, and with a large supply of water, to give a radius of action of 5,000 sea miles. With the same load on board, and with forced draft, the mean speed on a trial of "several hours" duration was, we are informed, 33.6 knots.

The four torpedo-boat destroyers are 59 meters long, equal to 193 feet 6¾ inches; the beam is 6.4 meters (21 feet), and the displacement 280 tons. The engines, which are balanced on the Schichau system, develop 6,000 indicated horse power. Engines and boat behaved well during the trials, notwithstanding the rough weather experienced.—"Engineering."

ENGLAND.

British Naval Progress.—It is our usual custom, says the London "Engineering" of December 23, to review at the end of the calendar year the progress made with warship building during the preceding twelve months; but as at the time of writing all interest is centered on the new work to be given out by the Admiralty to private contractors, we may depart from our ordinary practice and satisfy some part of the craving for prospective facts regarding these ships before turning to past progress. On December 16 last there were delivered at the

Admiralty tenders for a new armored cruiser to attain a speed of 23 knots, and on December 20 "bids" were similarly made for the construction of four battleships; while some time ago tenders were submitted for several new 30 to 32-knot torpedo-boat destroyers. This work is not yet given out. The battleships belong to the supplementary naval programme produced in the House of Commons in July, and there are yet four cruisers under this supplementary programme to be ordered, but the designs are not completed. The large cruiser was included with three others in the original Government programme of February last—a cruiser of the Cressy class has been ordered from Clydebank, another from Vickers' Naval Construction Works, at Barrow-in-Furness, and now the order for the larger cruiser is pending while her consort is to be built at the Pembroke Dockyard.

Taking the battleships, it may be said that they belong to a new class, but are more like the *Formidable* than the *Canopus*. Table I gives the leading particulars of all three classes, as well as of the *Majestic* type, with a note of the number built or projected. Table II refers to cruisers, while Table III gives the principal data of the official trials made in 1898.

H. M. S. Formidable.—This vessel, the launching of which on November 17, 1898, was noted in our last issue, is one of three designed by Sir William White as improved *Majestics*. She is 10 feet longer than the latter, and, while displacing 100 tons more, will have a draught of 9 inches less.

The leading dimensions are as follows: Length between perpendiculars, 400 feet; beam, 75 feet; mean draught, 26 feet 9 inches; displacement, 15,000 tons. She will be fitted with two sets of triple-expansion engines having collectively 15,000 I.H.P., and are to maintain a speed of 18 knots. Steam will be supplied by twenty Belleville boilers, working at a pressure of 300 pounds reduced to 250 pounds at the engines. Even with the less draught these vessels will carry 2,100 tons of coal, provision being made to coal the lower bunkers independently of the upper ones. The side armor is 9 inches thick, 15 feet deep, and 216 feet long, and is treated with the Harveyized process. The bulkheads are 9 to 12 inches thick and join the side armor, thus

TABLE I.—BRITISH BATTLESHIPS BUILT, BUILDING OR PROJECTED.

Type and date.	*Majestic* (1895).	*Canopus* (1897).	*Formidable* (1898).	New ships (1899).
Number included	Nine *	Six	Six	Four
Length between perpendiculars	390 feet	390 feet	400 feet	405 feet
Breadth	75 feet	74 feet	75 feet	75 feet 6 inches
Draught (medium)	27 feet 6 inches	26 feet	26 feet 9 inches	26 feet 6 inches
Displacement	14,900 tons	12,950 tons	15,000 tons	14,000 tons
Speed in knots	17.5	18¼	18	19
Indicated horse power	Nat., 10,418; for., 12,497	Natural, 13,500	Natural, 15,000	Natural, 18,000
Cylinders	40. in., 59 in., 88 in.	30 in., 49 in., 80 in.	31½ in., 51½ in., 84 in.	33½ in., 54½ in., 63 in., 63 in.
Stroke	51 inches	51 inches	51 inches	48 inches
Revolutions	106 †	108	108	120
Piston speed	901 feet	918 feet	918 feet	960 feet
Working pressure	155 pounds	300 lbs. to 250 lbs.	300 lbs. to 250 lbs.	300 pounds to 250 pounds
Boilers, number and type	8 S. E. cylindrical	20 Belleville	20 Belleville	24 Belleville
Heating surface	25,570 square feet	33,793 square feet	37,120 square feet	43,260 square feet
Grate area	821 square feet	1,050 square feet	1,170 square feet	1,375 square feet
Heating surface per I.H.P.	F. D. 2.04, N. D. 2.45 sq. ft.	2.50 square feet	2.475 square feet	2.4 square feet
I.H.P. per sq. ft. of grate area	F. D. 15.22, N. D. 12.68	12.85	12.8	13.1
Weight of machinery	1,300 tons	1,290 tons	1,400 tons	1,580 tons
Armament	Five tubes, four submerged, four 12-in. b. l. guns, twelve 6-in. q. f., eighteen 12-pounders, twenty smaller guns.	Four sets of torpedo tubes, 18 in., four 12-in. b. l. guns, twelve 6-in. q. f., ten 12-pounder q. f., and eighteen smaller guns and Maxims.	Two submarine torpedo tubes, 18 in. diam., four 12-in. b. l. guns, twelve 6 in. q. f., eighteen 12-pdrs., and twenty smaller guns.	Four sets of submerged 18 in. tubes, four 12-in. b. l. guns, twelve 6 in. q. f., twelve 12-pounder q. f., and other smaller guns and Maxims.
Armor: Belt	9 inches	6 inches	9 inches	7 inches to 4 inches
Armor: Bulkhead	14 in. to 9 in.	12 inches	12 inches to 9 inches	11 inches to 10 inches
Armor: Barbette	14 in. to 6 in.	12 inches to 5 inches	12 inches to 6 inches	10 inches to 7 inches

* All commissioned.

† Actual run on forced-draft trial for 12,497 indicated horse power.

TABLE II.—BRITISH CRUISERS BUILDING OR PROJECTED.

Class.	*Argonaut* class.	*Cressy* class.	*Powerful* class.	New cruisers.
Number	Eight	Six	Two	Two
Length between perpendiculars	435 feet	440 feet	500 feet	500 feet
Breadth	69 feet	69 feet 6 inches	71 feet	71 feet (extreme)
Draught	24 feet 7 inches	26 feet 3 inches	27 feet	26 feet
Displacement	11,070 tons	12,000 tons	14,200 tons	14,100 tons
Speed in knots	20¾.	21	22¼	23
Indicated horse-power	18,000	21,000	25,000	30,000
Cylinders	34 in., 55½ in., 64 in., 64 in.	36 in., 59 in., 68 in., 68 in.,	45 in., 70 in., 76 in., 76 in.,	43½ in., 71 in., 81½ in., 81½ in.
Stroke	48 inches	48 inches	48 inches	48 inches
Revolutions	120	120	114.4	120
Piston speed	960	960 feet	915 feet	960 feet
Working pressure	300 to 250 pounds	300 to 250 pounds	260 to 210 pounds	300 to 250 pounds
Boilers, number and type	30 Belleville	30 Belleville	48 Belleville	43 Belleville
Heating surface	47,300 square feet	51,500 square feet	69,576 square feet	71,970 square feet
Grate surface	1,390 square feet	1,650 square feet	2,193.6 square feet	2,310 square feet
Weight of machinery	1,630 tons	1,800 tons	2,258 tons	2,500 tons
I.H.P. per ton	11.6	11.67	11.08	12.00
Square feet of heating surface per I.H.P.	2.5 square feet	2.45	2.79	2.4
I.H.P. per square foot of grate area	13.6	12.7	11.4	13.0
Armament	Two submerged torpedo tubes 18 inches in diameter, sixteen 6-inch quick-firing, fourteen 12-pounder quick-firing and three 3 pounder quick-firing guns.	Two submerged torpedo tubes 18 inches in diameter, two 9.2-inch breech-loading, twelve 6-inch quick-firing, and seventeen smaller guns.	Four tubes, two 9.2-inch breechloading, twelve 6-inch quick-firing, and thirty smaller guns.	Same as *Powerful*

TABLE III.—OFFICIAL RESULTS OF TRIALS OF BRITISH BATTLESHIPS AND CRUISERS MADE IN 1898.

Name of ship.	Type.	Thirty hours' coal consumption trial.			N. D. trial, or thirty hours' coal consumption trial at higher powers.			Full-power trial.		
		I.H.P.	Speed.	Coal per horse power hour.	I.H.P.	Speed.	Coal per horse power hour.	I.H.P.	Speed.	Coal per horse power hour.
			Knots.	*Pounds.*		*Knots.*	*Pounds.*		*Knots.*	*Pounds.*
Illustrious	Battleship	6,155	14.51*	1.77	10,241	55.96*	.....	12,126	15.5*	.....
Furious	Fleet cruiser	2,260	13.6	2.34	7,133	18.7	2.1	10,272	20.1	.....
Vindictive	Fleet cruiser	2,153	12.6*	2,16	7,164	17.7*	1.83	10,263	20.1*	.....
Proserpine	Third-class cruiser	3,643	17.0*	2.4	5,336	19.7*	.....	7,145	21.0*	.....
Perseus	Third-class cruiser	3,627	17.2*	2.1	5,243	18.9*	.....	.....	.....	.....
Pegasus	Third-class cruiser	3,698	17.26*	1.96	5,400	20.0*	.....	7,134	21.2*	.....
Pactolus	Third-class cruiser	3,631	16.6*	2.46	5,428	19.1*	.....	7,201	20.5*	.....
Diadem	First-class cruiser	3,318	12.64*	2.21	12,813	19.53	1.61	17,262	20.65	1.77
					12,862†	.....	1.88	15,903	.....	.....
Europa	First-class cruiser	3,319	12.9*	2.23	12,770	.....	1.94	17,026	.....	1.91
					12,705†	.....	2.01	16,314	.....	.....
Niobe	First-class cruiser	3,348	12.0*	1.76	12,968	19.27	1.55	16,822	20.50	1.66
Andromeda	First-class cruiser	3,388	12.9*	1.98	12,621	19.3	1.74	16,751	20.41	1.7
Argonaut	First-class cruiser	3,756	13.15	2.13	13,815	19.86	1.6	18,894	21.17	1.6
		3,815	.....	2.02						

The *Illustrious* is the only vessel on the list with cylindrical boilers; the four third-class cruisers of the "P" class have small tube boilers—the *Proserpine* of the Thornycroft design, the *Perseus* of the Yarrow type, the *Pegasus* of the Reed design, and the *Pactolus* of the Blechynden patent. All these vessels had forced draft on the full-power trial. The other ships have the Belleville type, the *Furious* and *Vindictive* without economizers. The *Diadems* have such economizers, and all these attained their full power with natural draft.

* Speeds marked with an asterisk were taken by log; the others on the deep-sea Admiralty course on the Cornish coast. The low speed on full-power trial of *Illustrious* was due to the state of the sea.

† These trials—*Diadem* and *Europa*—were with only 78 per cent. of the boiler power.

forming a belt around the vitals of the ship. There are two protective decks 2.5 to 4 inches in thickness.

The armament consists of four 12-inch breech-loading wire-wound guns, two firing forward and two aft. These guns are in barbettes of 14 inches of steel, and the positions further protected with strong shields. The auxiliary armament is formed of twelve 6-inch rapid-fire guns of a new type, mounted in casements, eight on the main deck and four on the upper deck. In addition, sixteen 12-pounder rapid-fire guns are mounted, eight on the main deck and eight on the upper deck. Two 12-pounder boat guns, twelve 3-pounder rapid-fire guns and eight machine guns.

The 13-inch gun of the United States ordnance throws a larger projectile than the 12-inch wire-wound gun of the British ordnance. The 13-inch projectile weighs 1,100 pounds, against 850 for the 12-inch gun. The muzzle velocity of the 13-inch projectile is 2,100 foot-seconds, and of the 12-inch gun 2,367 foot-seconds. The perforation of the 13-inch gun at the muzzle is 33.5 inches of iron, and of the 12-inch gun 36.8 inches of iron.

There will be four 18-inch submerged torpedo tubes, two being fitted forward and two aft. In order to obviate any serious injury arising from the use of the ram, which is a steel casting weighing more than 30 tons, the sides forward are partly covered with a 2-inch nickel plating in addition to the ordinary skin plating, this stiffening extending from the ram to the belt.

H. M. S. Irresistible, a first-class, twin-screw, barbette battleship, was launched December 15, 1898, at Chatham. She is one of three big battleships now in course of construction, the other two being the *Formidable* and *Implacable*, which are respectively Portsmouth and Devonport ships. These vessels are to be each of 15,000 tons displacement, and are, therefore, just 100 tons beavier than the *Majestic* class, and no less than 850 tons above the *Royal Sovereign* class, which were the monsters of a few years ago. The *Irresistible* is 400 feet long between perpendiculars, and 75 feet extreme breadth. The draught of water is to be 20 feet 3 inches forward and 27 feet 3 inches aft. The coal at load draught is 900 tons, but there is a capacity for stowage

of 2,040 tons. Not many details have been made known respecting these big armorclad ships. The speed with natural draft is estimated at 18 knots, which is to be obtained with 15,000 indicated horse power. The engines are by Messrs. Maudslay, Sons & Field, and are of the now universal inverted three-stage compound type, supplied with steam by Belleville boilers, of which there will be twenty.

H. M. Cruiser Andromeda.—This vessel, which is one of the *Diadem* class of cruisers, is 435 feet long by 69 feet beam, and has a displacement of 11,000 tons on a draught of 26 feet. The propelling machinery, which has been constructed by Messrs. R. and W. Hawthorn, Leslie and Co., Ltd., of St. Peters, is of 16,500 indicated horse power. The twin-screw engines are of the four-crank triple-expansion type, each set having one high, one intermediate and two low-pressure cylinders, the diameters being 34 inches, 55½ inches, and two of 64 inches by 48-inch stroke. Steam is supplied by thirty boilers of the Belleville type, fitted with economizers. These boilers have a total heating surface of 40,140 square feet. The condensers, which are of gun metal, have a cooling surface of 17,500 square feet. The whole of the shafting is of hollow steel, the propellers being of gun metal. The boilers work at a pressure of 300 pounds per square inch, which is reduced at the engines, by means of Belleville reducing valves, to 250 pounds. The trials stipulated by the contract were three in number, namely: One of 30 hours duration at 3,300 I.H.P.; one of 30 hours duration at 12,500 I.H.P.; one of 8 hours duration at the full power of 16,500 I.H.P. The whole of these trials passed off without the slightest hitch of any kind, the contract conditions in all cases being more than realized. The following is a list of the results obtained: First 30-hours trial: I.H.P. 3,388; revolutions, 69¼; speed, 12.76 knots; coal consumption per I.H.P. per hour, 1.98. Second 30-hours trial: I.H.P., 12,621; revolutions, 107; speed, 19.31 knots; coal consumption per I.HP. per hour, 1.74. Eight-hours full-power trial: I.H.P., 16,750; revolutions, 117; speed, 20.4 knots; coal consumption per I.H.P. per hour, 1.76. The *Andromeda* was built at H. M. Dockyard,

Pembroke, but went round to Portsmouth to be completed and to receive her armament.

Steam Trials of H. M. S. "Ariadne."—This first-class protective-deck cruiser of the improved *Diadem* class, built and engined by the Clydebank Engineering and Shipbuilding Company, Limited, on the Clyde, completed on Tuesday, the 7th February, 1899, a series of contract steam trials. The *Ariadne*, so far as the hull is concerned, in which which we include offensive and defensive qualities, resembles closely the *Diadem* class, and the only difference is in the boilers. The boilers of the later ships have been designed with slightly more heating surface than the *Europa*, 47,300 square feet of heating surface, and 1,390 square feet of grate area, the ratio being 34.0 to 1; while in the case of the *Europa*, with the same number of boilers, the ratio is 27.73 to 1, the heating surface being 40,600 square feet, and the grate area 1,450 square feet. It will be seen that the coal burned per square foot of grate per hour is higher. On the full-power trial it was nearly 22 pounds per square foot of grate, as against 21 pounds in the *Diadem* class. The power per square foot of grate was 13.2 indicated horse power, as against 11.63 indicated horse power in the *Europa;* but in special trials both these results have been exceeded. The heating surface is equal to 2.48 square feet per unit of power maintained; in the *Europa* it was 2.38.

In each type of ship there are thirty Belleville boilers, with economizers. The engines are of the triple-expansion type, but the arrangement in the *Ariadne* differs from that in the *Europa*. Instead of the four cylinders being placed as follows from the bow end, high-pressure, intermediate pressure, and the two low-pressures with the valves between each, the order is as follows: low-pressure slide valve, low-pressure cylinder, high-pressure cylinder, high-pressure piston valve; intermediate-pressure piston valve, intermediate pressure cylinder, low-pressure cylinder and low-pressure piston valve. Thus the cylinders are in pairs as closely together as is possible, and the sequence of cranks is, high pressure, intermediate pressure, forward low pressure, after low pressure, the first and third named being at right angles, as

are the other two. This arrangement gave practically no vibration. The diameters of cylinders are 34 inches, 55½ inches, 64 inches and 64 inches, by 48 in stroke. They were designed to give the full power at 120 revolutions, while in the case of the *Europa* the designed speed was 110 revolutions, although with 112.4 revolutions 17,010 indicated horse power was got, while the *Ariadne* got 19,156 indicated horse power with 118.9 revolutions.

RESULTS OF STEAM TRIALS OF H. M. S. *ARIADNE*.

Description of trial	30 hours' coal consumption at 3,600 I.H.P.	30 hours' coal consumption at 13,500 I.H.P.	8 hours' full power
When tried	Jan. 31 and Feb. 1, 1899.	February 3 and 4, 1899	February 6, 1899
Draught of water Forward	25 ft. 5 in.	24 ft. 8½ in.	24 ft. 3 in.
Draught of water Aft	26 ft. 2 in.	25 ft. 11½ in.	26 ft. 3 in.
Displacement	—	—	—
Actual load on safety valves, pounds	300	300	300
Pressure of air in stokehold, in. of water	...	...	.23
Average pressure at boilers	218	262	288
Average pressure at engines	202	227	240
Receiver pressures H.P.	143.5	206.5	229
Receiver pressures I.P.	34.5	58.5	75.5
Receiver pressures L.P.	5	18	24.5
Average vacuum	24.8	25.5	25.3
Mean pressure in cylinders H.P.	20.6 | 17.7	84.2 | 87.5	103.4 | 104.7
Mean pressure in cylinders I.P.	17.3 | 18.1	32.9 | 33.1	40.3 | 41.9
Mean pressure in cylinders L.P. forward	7.8 | 8.3	16.3 | 16.7	21.3 | 21.1
Mean pressure in cylinders L.P. aft	7.6 | 7.3	17.4 | 16.4	22.6 | 20.9
Mean number of revolutions per minute	70.3	109.1	118.9
Indicated horse power, total	3,758	14,046	19,156
Speed, knots	13.3	20.1	21.5
Force of wind	2 to 3	1 to 6	2 to 3
State of sea	Slight swell	Smooth to moderate	Moderate swell
Propeller Diameter	17 ft.	—	—
Propeller Pitch	21 ft. 6 in.	Same	Same
Consumption per indicated horse power per hour	2.05	1.73	1.66

The *Ariadne* is 435 feet long between perpendiculars, 69 feet beam, and at 24 feet 7 inches draught has 11,070 tons displacement.

Steam Trials of H. M. S. Argonaut.—The first-class cruiser *Argonaut*, built and engined by the Fairfield Shipbuilding and

Engineering Company, Limited, Govan, has completed her series of contract trials with very satisfactory results, as the appended table shows. She is of similar design to the four vessels of the *Diadem* class, and is the first of a second quartette, including the *Ariadne*, delivered to the Admiralty recently by the Clydebank Company, the *Amphitrite*, ready at Vickers' Works at Barrow-in-Furness, and the *Spartiate*, in progress at the Pembroke Dockyard. The boilers have slightly more surface than those of the *Diadem*, and the engines, although of the same dimensions, are required to work at 120 revolutions, instead of 110 per minute, and to develop 18,000 indicated horse power, against 16,500 indicated horse power, giving the ship a speed of 20¾ knots as compared with 20½ knots. As a matter of fact, the *Argonaut's* machinery on the full power worked at a mean of 128.4 revolutions, developed 18,894 indicated horse power, and gave the ship when down to her designed draught, a speed of 21.17 knots, instead of 20.75 knots. The *Argonaut*, it may be well to state, is 435 feet long, 69 feet beam, and 24 feet 7 inches draught, at which the displacement was 11,000 tons. The engines are of the four-crank type, but working triple-compound, the diameters of cylinders being 34 inches and 55½ inches with two of 64 inches, a stroke of 48 inches, so that the full power required a piston speed of 1,027 feet per minute. The vessel has thirty Belleville boilers with economizers, the total heating surface being 47,300 square feet, and of grate area 1,390 square feet, so that on the full-power trial the power was equal to 13.6 units per square foot of grate, while the ratio of heating surface to power was 2.5 square feet to 1 of power.

This total power of 18,894 indicated horse power was made up as follows :

Mean indicated horse power	High	2,891	2,869
	Intermediate	2,413	2,510
	Forward, low	1,988	1,921
	Aft, low	2,319	1,983
	Total	9,611	9,283
	Grand total		18,894

RESULTS OF STEAM TRIALS OF H. M. S. *ARGONAUT*.

Description of trial	30 hours' coal consumption at 3,600 I.H.P.	30 hours' coal consumption at 13,500 I.H.P.	8 hours' full power	30 hours' coal consumption at 3,600 I.H.P.
When tried	Nov. 25 and 26, 1898	Nov. 29 and 30, 1898	December 3, 1898	Dec. 7 and 8, 1898
Draught of water.....{ Forward...	24 feet 3 inches	Same	Same	Same
Draught of water.....{ Aft.....	26 feet 3 inches	Same	Same	Same
Displacement, tons	...	...	...	...
Actual load on safety valves, pounds	300	300	300	300
Pressure of air in stokehold, inch of water	...	...	.21	...
Average pressure in boilers	226	Variable	293	Variable
Average pressure at engines	133	Variable	...	Variable
Receiver pressures.....{ H.P...	135	Variable	238	Variable
Receiver pressures.....{ I.P....	40	Variable	94	Variable
Receiver pressures.....{ L.P...	8	Variable	23	Variable
Average vacuum	25.1	26.6	25.6	26
Mean pressure in cylinders. H.P	35.7 | 34.5	85.2 | 83.5	102.1 | 101.9	36.9 | 33.9
Mean pressure in cylinders. I.P.	10.7 | 10.6	24.8 | 26.3	31.9 | 33.5	11.8 | 13.1
Mean pressure in cylinders. L.P. For'd.	7.1 | 6.6	16.4 | 15.3	19.8 | 19.2	6.4 | 6.4
Mean pressure in cylinders. L.P. Aft.	7.9 | 7.3	18.6 | 16.3	23.1 | 19.9	6.8 | 5.9
Mean number of revolutions per minute	74.6	116	128.4	75.9
Indicated horse power (total)	3,756	13,815	18,894	3,815
Speed, knots	13.15	19.86	21.17	...
Force of wind	4 to 7	1 to 5	...	3 to 7
State of sea	Smooth	Smooth	...	Moderate to slight
Propeller.....{ Diameter	17 feet	...	...	...
Propeller.....{ Mean pitch	S. 20 feet 5 7/16 inches P. 20 feet 6 inches	Same	Same	Same
Consumption per indicated horse power per hour	2.13	1.6	1.62	2.02

This was realized, as indicated in the table above, by only 0.21 inch of pressure indicated on the water gage, and it will be remembered that in the old cylindrical-boiler days anything under 0.5 inch was considered natural draft. The rate of combustion on this trial was 21.9 pounds per square foot of grate. This, of course, has been excelled in the Navy with the Belleville boiler; it may be remembered, for instance, that the *Diadem*, in her special trials, realized 14.11 indicated horse power per square foot of grate, 1.99 square foot of heating surface being sufficient for each horse power, the coal burned per square foot of grate being 27.52 pounds. And even then the pressure was only 0.3 inch. The *Argonaut* has thus much in reserve, even when doing 18,894 indicated horse power and 21.17 knots, nearly half a knot in excess of the design. This speed, like all the rates at various powers, was determined by four runs on the deep-sea course between Rame Head and Dodman Point, when the vessel was at her full load displacement. The full power realized, it may be said, is equal to 11.6 indicated horse power per ton weight of all machinery, which, with the liberal boiler and bearing-surface allowances, is a very satisfactory result, and on it Sir John Durston is to be congratulated.

H. M. Torpedo-Gunboat Sheldrake has just completed a series of most interesting trials on her boilers. The basin trials of this vessel took place at Devonport on the 14th, 15th, 16th and 17th November, and the sea trials were carried out off Plymouth on November 28 and December 1. There are four boilers in this ship of the well-known Babcock and Wilcox type, having a collective heating surface of 9,424 square feet, and a total grate area of 252 square feet. 4,050 I.H.P. was obtained on the sea trials when burning about 25 pounds of coal per square foot of grate per hour with $\frac{1}{2}$-inch air pressure in the ashpits; with this power the vessel obtained a speed of 20.6 knots per hour on a coal consumption of 1.57 pounds per I.H.P. per hour. When burning only 15 pounds of coal per square foot of grate per hour, the average I.H.P. was 2,642; the speed obtained with this power was 17.9 knots per hour, and the coal consumed per I.H.P. per hour was 1.42 pounds.

English Torpedo Boat Trials.—The London correspondent of the "Glasgow Herald" furnishes some interesting results of trials of torpedo-boat destroyers during the year 1898, and in opening his article briefly notes the extent of the progress made with the fleet of boats ordered. There were, he says, forty-two in the first fleet of 27-knot boats, and three of these, by White, of Cowes, passed through their trial with about a tenth of a knot to spare, although the power was somewhat abnormal, between 4,800 and 5,070 indicated horse power. Two, built at Paisley, have yet to pass through the ordeal—they are being fitted with water-tube boilers; and the others have had long periods of commission, and have done well, although water-tube boilers have had to be ordered for some of the first, which had locomotive boilers. Fifty-four faster vessels were ordered, including four of 32 knots or more, the *Arab*, from Clydebank; the *Albatross*, from Thornycroft; the *Express*, from Laird; and the *Viper*, from Fairfield. The other fifty were to steam 30 knots, and of these fifteen have passed through their trial during the year just closed, fourteen succeeded the previous year, and there remain twenty-one of the 30-knot and the four faster boats still to try, of which five have not yet been launched. Last year Laird, Fairfield and Palmer each passed three through their runs. Vickers, of Barrow-in-Furness, Doxford, of Sunderland, and Thornycroft, of London, have each succeeded in the trials of two boats. The power necessary has varied very much. The lowest was with one of Thornycroft's boats, 5,892 indicated horse power, which gave almost the highest speed got, 30.4 knots; while Vickers, with the *Avon*, about equaled this with 5,986 indicated horse power and 30¼ knots, the sister boat from the Barrow works doing 30.35 knots for 6,412 indicated horse power.

The highest power was registered in one of Laird's boats, which developed 7,090 indicated horse power, and only got a small fraction over 30 knots. Another of the same builder's boats registered 6,848 indicated horse power for 30.16 knots; but a third made 30¼ knots for 6,146 indicated horse power. Thornycroft's powers are low; the others, with one or two exceptions, range about 6,000 indicated horse power upwards. The

highest speed last year was with the *Aerial*, Thornycroft's boat, 30.6 knots; next Palmer's *Flying Fish*, 30.48 knots; Palmer's *Fawn*, 30.46 knots; Thornycroft's *Angler*, 30.40 knots; *Barrow's Bittern*, 30.35 knots; Fairfield's *Osprey*, 30.31 knots; Laird's *Wolf*, 30.26 knots; Vicker's *Avon*, 30.25 knots, and Fairfield's *Gipsy* and *Fairy*, 30.20 knots. As to coal consumption, the lowest return was in the case of the *Aerial*, 2.02 pounds; but this was exceptional, and, moreover, extreme accuracy in this respect under the trying conditions is difficult of attainment. As a rule, the slightest fraction under the stipulated 2½ pounds is satisfactory, and in one or two cases it was more, necessitating an extra load, which placed some of the ships at a slight disadvantage as to speed. Two of the 32-knot boats have had frequent preliminary trials, but none have pulled off their speed. The *Albatross* has done 31¼ with 7,500 indicated horse power, and it is hoped 32 knots will be got; but it will probably need more than the assumed 8,000 indicated horse power, which means a piston speed of 1,340 feet per minute, with over 4,000 revolutions per minute. Meanwhile Yarrow has passed through a preliminary trial the first of his Japanese boats, and got 31 knots for a trifle over 6,000 indicated horse power.—"Naval and Military Record."

FRANCE.

New Armored Cruisers.—The new first-class triple-screw armored cruisers *De Gueydon*, *Dupetit-Thouars* and *Montcalm* are to be vessels of the following dimensions: Length between perpendiculars, 448 feet 6 inches; extreme beam, 62 feet 9 inches; depth of hold, 22 feet 6 inches; mean draught, 22 feet 9 inches; displacement, 9,500 tons; coal stowage, 1,025 tons.

As in the *Jeanne d'Arc*, the protection consists of a cellular space comprised between the two armored decks, covered on the outside by an armor belt in two streaks; the lower of which, 6 inches in its thickest part at the water-line, but tapering off below and toward the extremities of the ship, extends from 4 feet 9 inches below the water line to 1 foot above; the upper belt, 3.8 inches thick, extends from the upper edge of the lower belt to the upper armor deck, except forward, where it is carried

right up to the forecastle deck, while aft it stops immediately abaft the rudder, the two ends being joined by a transverse armored bulkhead, which reaches to the double bottom. Two other armored bulkheads, one before the after turret, the other abaft the foremost one, shut in the central battery on the upper deck. The lower armored deck, which is nearly on a level with the water line amidships, is 1.2 inches thick on the central flat part and 2 inches thick on the slopes, which extend to the lower shelf of the armor belt; the upper armored deck is formed of two $\frac{1}{2}$-inch plates of hardened steel. The cellular cofferdam is similar to that in the *Jeanne d'Arc*, and is formed by two longitudinal water-tight bulkheads; the space enclosed between the first of these and the ship's side is divided into numerous compartments filled with cellulose, while the space between the two bulkheads serves as a collector for the water which may come through the armor and cofferdam, numerous water ways being fitted to conduct this water to the hold. The large space enclosed between the two inner bulkheads is also subdivided as much as possible, while all the trunks leading through it, funnels, ammunition tubes, ventilators, etc., are protected by armored combings and a cofferdam. The superstructures differ a little from those of the *Jeanne d'Arc*, the spar deck being continued almost right aft, while the turret for the after 19-centimeter gun is raised above it instead of being on the upper deck, as in the earlier ship. The bridges also not so large, there being only a small one between the after funnel and the mizenmast, and a somewhat larger one between the two foremost funnels and the foremast, round which it is carried, on it before the mast being the armored conning tower, the chart house, and look out places.

The armament of these ships will consist of two 19.4 centimeter (7.6-inch) guns in armored turrets, one forward and one aft, eight 16.4-centimeter (6.4-inch) quick-fire guns in armored casemates, four 10-centimeter (3.9-inch) quick-fire guns on the spar deck, sixteen 3-pounder quick-fire guns distributed in the tops and other parts of the ship, and six 1.5-pounders with two submerged torpedo tubes. The eight 16.4-centimeter quick-fire guns are mounted two forward and two aft in the angles of the case-

mate, with an arc of training which enables them to be fired from right ahead and right astern to the beam respectively, the remaining four being mounted on the broadside. The casemates are protected exteriorly by steel plates extending from the upper to the spar deck, their internal faces, as well as the roofs and platforms, being also made of hard steel armor; the carriages of the gun are also fitted with steel shields, so that the open part of the gun port is reduced to a minimum. The 10-centimeter quick-fire guns are protected by two shields, one fixed, the other moving with the gun. The ammunition tubes for the two 19.4-centimeter guns lead straight up into the turrets, those for the smaller guns lead up inside the cofferdam to the casemate.

The ships are to be driven by three screws; the engines, each in a separate compartment, develop together 19,600 I.H.P., which is to give under forced draft a speed of 21 knots. The *Montcalm* is to be provided with twenty Normand-Sigaudy water-tube boilers, the *Dupetit Thouars* twenty-eight Belleville, and the *De Gueydon* twenty-five Niclausse. The ships will be lighted and the guns and ammunition hoists worked by electricity, which will be provided by four dynamos. The normal provision of coal is 1,025 tons, which will give a radius of action at 10 knots of 6,500 miles, or of 1,230 miles at full speed. With all reserve places filled with coal, the radius at 10 knots is increased to 10,300 miles, and at full speed to 1,920; or they can run at full speed for 61 hours with their normal coal supply and for 90 hours with the extreme limit of stowage. The "Yacht" complains that in this class of vessel the coal supply and consequent radius of action is too small, and that the guns in the central redoubt are insufficiently protected.—"Le Yacht" and "Le Temps."

French submarine torpedo boats.—Lieutenant Darefus, of the French Navy, has been at work for the past eight years on boats of this type, and six of his designs are to be built in 1899. These boats are not fully described, but they are to be 111 feet long, 12 feet beam, 5 feet maximum draught on surface, 106 tons displacement, and the 217-H.P. engines will operate a single screw and drive the vessel at a 12-knot speed at the surface. These boats will be identical with the *Narval*, now build-

ing at Cherbourg. They are to have a surface-steaming radius of 250 knots, and an underwater radius of 100 knots at a 10-knot speed. On the surface they will be propelled by steam, and by electric accumulators below the surface, with dynamos on board to charge the accumulators. One of them, the *Zede*, has been tested at Toulon, and is said to have made an underwater trip of 40 miles.

GERMANY.

Kaiser Frederick III has recently made successful trial trips. She was the first of the five first-class battleships built under the new programme, and is a triple-screw ship of 11,130 tons displacement. Her dimensions are: Length, 377 feet 4 inches; beam, 67 feet; draught, 25 feet 8 inches. Protection is afforded by an all-around water-line belt of hardened steel 11.8 inches thick, tapering away at the bow and stern, and a 3-inch armored deck.

The main battery consists of four 9.2-inch guns of newest pattern, mounted in two Harveyized steel turrets, one fore and one aft, of 9.8-inch thickness. The secondary battery contains eighteen 5.9-inch, twelve 3·3-inch, twelve 1.4-inch quick-fire guns and also twelve 3-inch machine guns. The 5.9-inch quick-fire guns are protected either by turrets or casemates.

The engines for each of the three screws are in their own separate water-tight compartment. These engines were built by the Government establishment at Wilhelmshaven.

There are eight cylindrical boilers and four water-tube boilers.

On forced-draft trial the engines developed 13,500 I.H.P., or 500 H.P. over contract, making 115 revolutions per minute and securing a speed of 18 knots, although a heavy sea was running at the time.

Baiern.—This battleship made a six-hours forced-draft trial lately, developing 6,386 I.H.P. for a speed of 15.5 knots average.

Freya.—This new second-class cruiser has also completed a satisfactory, full-speed trial, developing 10,500 I.H.P., and making 20 knots average speed. She is fitted with Niclausse water-tube boilers.

RUSSIA.

The Russian naval programme is, according to a published statement by Lord Charles Beresford, as follows: One

hundred and seventeen million dollars is to be expended during the period of 1898–1904 upon the construction of eight first-class battleships, six first-class cruisers, ten second-class cruisers, one submarine transport, one torpedo transport, twenty torpedo-boat destroyers and thirty torpedo boats. The battleships will all be of 12,900 tons, 368 feet in length, 72 feet 6 inches beam and 26 feet draught, and to have a speed of 18 knots under natural draft. One is being built by the Cramps at a contract cost of $4,358,000, to be delivered in thirty months; four are being built at the Government yards in Russia, one in France, and two are still unassigned. Of the first-class cruisers of 6,000 tons and 23-knot speed, Cramps are building one, two have been placed in France, two are being built by a Belgian firm at Nicolaieff, and builders in Germany have been invited to bid on the remaining large cruiser and one of the 3,000-ton cruisers, of which latter nine are still to be assigned. Six torpedo-boat destroyers of 312 tons are building at the Neroskey Works, St. Petersburg, and six of the same size in France; they are all to have a speed of 29 knots under natural draft. German shipyards have been offered a chance to bid on eight boats of 350 tons. Finland is building four 150-ton torpedo boats to steam 29 knots under forced draft, and the remainder will be built in Russian yards. The total of this naval programme is seventy-six vessels of 199,744 tons. There is quite a number of battleships and cruisers not yet placed, and the builders of the *Oregon* should have an opportunity to compete with Eastern and foreign shipbuilders and furnish vessels to serve as samples of what constitutes efficiency in working and in construction.

JAPAN.

Chitose.—The protected cruiser *Chitose*, built by the Union Iron Works, San Francisco, for the Imperial Japanese Navy, exceeded all expectations. On her official trial she made a six-hour run over the course in Santa Barbara channel, averaging 21.048 knots per hour, whereas but 20.5 knots are required, and developing a maximum speed of 21.38 knots under natural draft. On her forced-draft trial just completed, she averaged 22.87

knots per hour for two hours, the highest speed being 23.76 knots. The contract calls for the maintenance of only 22.5 knots during two consecutive hours.

The data as to horse power and efficiency of propeller has not been completely worked out, but the indications are that with less than 135 revolutions the vessel will make 20.5 knots. Evolution tests made under full speed were very successful, the *Chitose* turning in a radius of 300 feet, and being stopped from full headway to going astern within her own length.

The contract for the *Chitose* was signed at Washington, D. C., December 31, 1896. The first piece of keel was laid May 1, 1897. The first rivet was driven June 26, 1897, and the vessel was launched January 22, 1898. It is expected that she will be ready for her trial some time this month (January, 1899). Principal dimensions and other particulars of the vessel are as follows:

Length over all, feet and inches	405.2
Length, load-water line, feet and inches	396.0
Length, between perpendiculars, feet and inches	376.5
Breadth, moulded, feet and inches	49.0
Draught, normal, feet and inches	17.7½
Displacement, tons	4,760
Speed, knots	22½
I.H.P.	15,500
Coal capacity (total) tons	1,000

Engines, twin screws; one four-cylinder triple-expansion engine on each screw.

H.P. cylinder, diameter, inches	40
I.P. cylinder, diameter, inches	60
Two L.P. cylinders, diameter, each, inches	66
Stroke, inches	36
Revolutions per minute	150

Piston valves on H.P. cylinder; slides on I.P. and L.P.; cast-steel bed plates; forged-steel framing.

Main boilers.—Twelve single-ended, cylindrical, four-furnace boilers. Working pressure, 155 pounds.

ONE BOILER.

Mean diameter, feet and inches	14–0
Length over heads, feet and inches	9–3¾
Number of furnaces	4

Diameter of furnaces	Least, feet and inches	2–10
	Greatest, feet and inches	3–2
Thickness, inch		$\frac{1}{2}$
Number of combustion chambers to each boiler		2.
Thickness of combustion chamber sheets, inch		$\frac{9}{16}$
Heating surface:		
Four hundred and thirty $\frac{3}{4}$-inch charcoal-iron tubes, square feet		1,540.8
Four furnaces, square feet		140.2
Two combustion chambers		248.0
Heating surface, one boiler, square feet		1,929.
Heating surface, twelve boilers, square feet		23,148.
Area through tubes, one boiler, square feet		9.12
Grate area, one boiler, square feet		66.00
Ratio H.S. to G.S.		29.2 to 1.
Steam capacity 5 inches above top of combustion chamber, cubic feet		296.5
Morison's suspension furnaces used.		
Thickness of shell plates, inches		$1\frac{1}{16}$
Thickness of top parts of heads, inch		1
Thickness of tube sheets, inch		$\frac{3}{4}$
Thickness of bottom parts of heads, inch		$\frac{3}{4}$
Closed fire room, forced draft.[1]		

The *Chitose* will carry a heavier armament than either of the United States cruisers *Minneapolis* or *Columbia*. It will be supplied by the Japanese Government and will consist of two 8-inch quick-firing guns at the sides, ten 4.7-inch quick-firing rifles mounted in broadsides, with a secondary battery of twelve 12-pounder quick-firing rifles and six 2.5-inch Hotchkiss guns. There will be five torpedo tubes, 14 inches in diameter. This cruiser has two steel masts provided with fighting tops, in which the rapid-firing guns will be placed. She is equipped with four powerful searchlights and there are eight steering stations to provide for almost any contingency. Engines are protected by solid steel hatches.

A New Japanese Battleship.—The new battleship for the imperial Japanese Navy, the construction of which Messrs. Vickers, Sons and Maxim, Limited, are now commencing at their Naval Construction Works at Barrow-in-Furness, is to be 400 feet long between perpendiculars, 76 feet beam, with a draught of 27 feet 3 inches, this being the limit for Japanese waters, and the displacement will be 15,200 tons. The armor will extend right to

the ram, and will vary from 9 inches to 4 inches in thickness. The barbettes will be of 14 inches to 10 inches steel, and the protective deck will be 4 inches on the slopes and 2½ inches on flat part. The engines will develop 15,000 indicated horse power, giving the ship a speed of 18 knots, when running at their normal piston speed. Belleville boilers will be used, 25 or 26 in all, and they will be as liberal in their proportions as in the case of the boilers of recently-constructed British battleships, while the working pressure will be 300 pounds at the boilers and 250 pounds at the engines. The twin engines will be of the triple-expansion type, with three cylinders, the diameters being: High pressure, 31 inches; intermediate, 50 inches, and low pressure, 82 inches, with a stroke of 48 inches. The armament will consist of four 12-inch breechloading guns, mounted in pairs in barbettes, two at the forward and two at the after end of the vessel; fourteen 6-inch quick-firing guns, ten being placed on the main deck and four on the upper deck; twenty 12-pounder quick-firers in suitable positions on the upper and main decks; a large number of machine guns, and four submerged 18-inch torpedo tubes.

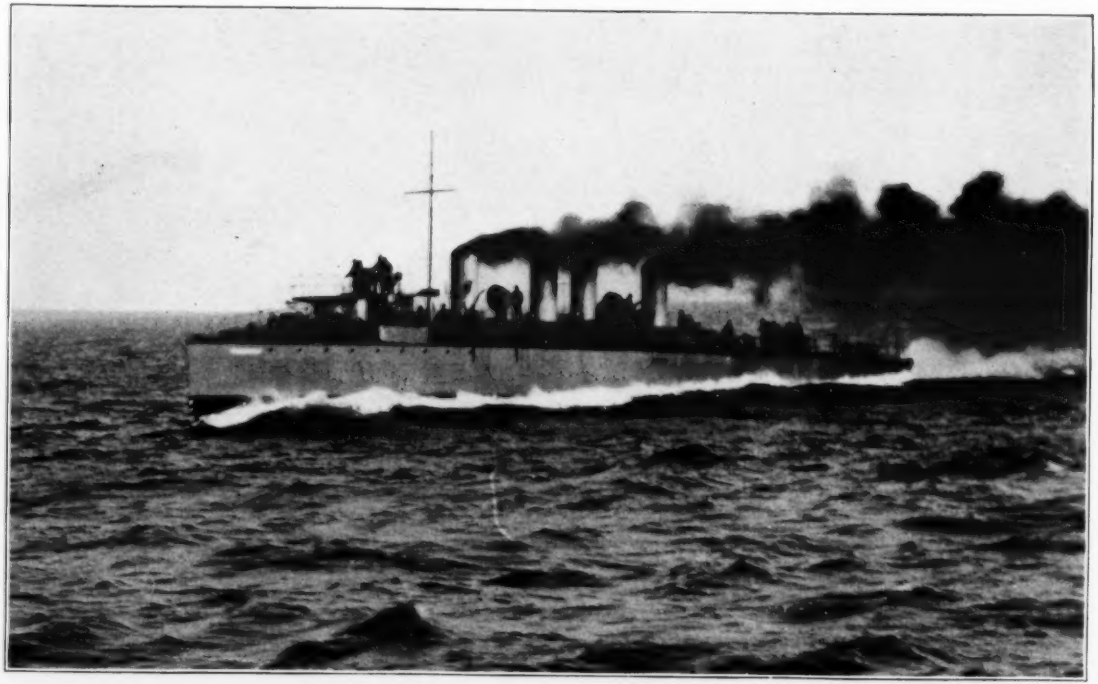
Ikadsuchi.—We here give a view of a torpedo-boat destroyer, built by Messrs. Yarrow and Company, Limited, for the Imperial Navy of Japan. This vessel ran a preliminary trial on December 16 over the Maplin measured mile with remarkable results, and it may here be stated that our illustration is a reproduction of a photograph taken from a tug, when the vessel was actually traveling at over 31 knots, the exposures of the plate having been made whilst the vessel was on the mile. The *Ikadsuchi*, for that is the vessel's name, is the first of six similar craft built by Messrs. Yarrow and Company, for Japan. She is a twin screw boat 220 feet long, and 20 feet 6 inches wide, and is propelled by two sets of four-crank triple-expansion engines, which are balanced on the Yarrow, Schlick, and Tweedy principle; this method has been adopted with considerable success by builders of larger vessels. It may be added that on the trial of the *Ikadsuchi* the running was exceedingly steady at all speeds. In each set of engines the high-pressure cylinder is 20½ inches,

the intermediate cylinder 31½ inches, and the two low-pressure cylinders each 34 inches in diameter, the stroke being 18 inches. In accordance with the usual practice now followed by this firm, the two low-pressure cylinders are placed at the ends of the set. There are four boilers of the Yarrow straight-tube type.

On the trial made on the 16th instant, the contract load of 35 tons was carried, and the contract speed of 31 knots was more than reached during four runs on the mile, without pressing the machinery. The engines are designed to give 6,000 horse power, but it was shown by the trial that an ample margin has been allowed, and it is estimated that 7,000 indicated horse power could be reached if needed. The steam pressure on trial averaged 185 pounds per square inch. The revolutions were 410 per minute, and the draught 8 feet 6 inches. The armament will consist of one 12-pounder quick-firing gun mounted aft, and five 6-pounder guns. There are two torpedo guns on deck for 18-inch torpedoes. The coal capacity is 90 tons, which is amply sufficient to take the vessel across the Atlantic at a fair speed. The official trials of these six vessels will take place during the new year, and to judge by the trip made with the *Ikadsuchi*, the Japanese authorities need have little doubt that Messrs. Yarrow and Co. will amply fulfil the certainly onerous conditions of their contract, and more than reach the exceptional speed promised.

TORPEDO-BOAT DESTROYER FOR JAPAN.

The first of six torpedo-boat destroyers built for the Imperial Navy of Japan by Messrs. J. I. Thornycroft and Company, of Chiswick, underwent her official trial trip off the mouth of the Thames on Monday the 5th inst., making a speed of 30¼ knots in a three hours' run. This vessel is of the same type and dimensions as the 30-knot boats built by the same firm for our Navy. Messrs. Thornycroft have four of the latter vessels ready for delivery besides H. M. S. *Albatross*, which is now under trial. It will be remembered that this vessel is one of the two experimental destroyers of higher speed ordered by the Government some time ago.



JAPANESE TORPEDO-BOAT DESTROYER "IKADSUCHI."

(STEAMING AT 31 KNOTS PER HOUR.)

The *Murakumo*, which means "The Darkening Clouds," is 210 feet long, 19 feet 6 inches wide, and 7 feet deep, the mean draught being 5 feet 8 inches. She has twin screws, and is built of special steel of a high tenacity, being about 40 tons. The armament consists of two 18-inch torpedo tubes, five 6-pounder quick-firing guns, and one 12-pounder quick-firing gun. The latter is mounted in the stern of the vessel instead on the conning tower, as in the English boats.

The engines are of the usual balanced type adopted by Messrs. Thornycroft for these craft, having cylinders 20 inches, 29 inches and two of 30 inches in diameter, with a stroke of 18 inches, running at 400 revolutions per minute, thus giving the very high piston speed of 1,200 feet per minute.

MERCHANT STEAMERS.

Oceanic.—The Oceanic Steam Navigation Company's splendid new vessel was successfully launched January 14, and before the end of 1899 will be on her station. Up to that time little had been known concerning her, but we are now enabled to give a few of the leading particulars of the great ship.

In the new *Oceanic* we will have a vessel of from a knot and a half to two knots less speed than the fastest vessels at present afloat. In short, her average speed will be from 20 to 21 knots, although there is a 23-knot liner building in Germany of smaller size than the *Oceanic*. She will thus be a little faster than the *Teutonic*, and the fact that she will be the largest vessel in the world, though not so fast as the *Campania*, *Lucania* or *Kaiser Wilhelm Der Grösse*, constitutes her a pioneer ship.

Every effort is being made in the new vessel to render her even more uniform in her passages than her predecessors in the fleet, one of which, the *Britannic*, earned for herself the expression, "as regular as a railway train." The *Oceanic* will be over 5,000 tons larger than any liner of her speed, and nearly 3,000 tons larger than the present largest vessel in the world. She will be twice the size of the largest battleship afloat. It is proposed ordinarily to drive her at about 20 knots, but she will be capable of 21 knots for the voyage if necessary, or about the same speed as the *St. Paul*. In stormy weather, therefore, she will be "let out," and similarly will make good any other delays on an ordinary voyage. The idea is to make her arrive at New York or Liverpool early on Wednesday mornings, having left the other side the previous Wednesday, and never to be so late as Wednesday evening or so early as Tuesday evening.

The *Oceanic* will, in external appearance, much resemble the *Teutonic*, except that her funnels will be much higher proportionately, in accordance with recent practice. They will be of

the same size, height and distance apart as the *Campania's*, but owing to the vessel's vast size they will look much smaller, there being three masts also, instead of two, as in the case of the *Campania*. The three masts will mean greater convenience in dealing with cargo, and will also make her look more like a ship than the abnormally-funnelled and two-masted vessels now common. There will be no turtle backs, but otherwise the arrangements on deck will be very similar to those of the *Teutonic*.

Her gross tonage is 17,040, displacement 28,500 tons; length over all, 705 feet 6 inches, by 68 feet beam, by 49 feet 6 inches moulded depth. The total depth is about 68 feet, and the length between perpendiculars about 685 feet. The extreme load draught will be about 32 feet 6 inches. There will be fifteen fire-tube boilers—twelve double and three single ended—of about 1,100 tons total weight. The engines will be triple, four-cylinder, four-crank, balanced, as in the *Kaiser Wilhelm Der Grösse*, of about 28,000 indicated horse power, working with 195 pounds of steam, and driving two three-bladed propellers, 22 feet diameter, placed very close together, with an opening between them, the circumferences of the tip circles being about 9 inches apart in same plane. The cylinders are 47½, 79 and two of 93 inches diameter, by 6 feet stroke, and the crank shafting is 25 inches diameter with crank pins 26 inches diameter.

The forefoot is cut away, and the deadwood is also similarly lessened, the keel raking up aft for about 40 feet. The propeller shafts are protected by the skin plating and frames of the ship, no part of the shafting being exposed, and the stern brackets not being visible from the outside, after the method first introduced for twin-screw vessels by Mr. Pirrie in the *Teutonic* and *Majestic*. There is a very long forecastle, and the strake under the upper deck from forecastle to the poop is specially strengthened by very large round-headed rivets. This is the only part of the ship in which round-headed rivets have been used. Everything in the construction of the vessel points to extraordinary strength, the object being to minmize depreciation.

The vessel will have the largest electric-light installation fitted on shipboard. There will be twenty-two ordinary life boats. Her

bilge keels are 18 inches deep, and she is flatter on the floor than the *Teutonic*, and she has less "tumble home." As a cruiser she will be able to steam 24,000 nautical miles at 12 knots—or round the world—without coaling. The *Teutonic*, which next to her possesses the greatest coal endurance of any vessel—war or merchant—can steam 21,600 miles at 10 knots. This means that the *Oceanic* will steam 23,400 miles in eighty-one days, and the *Teutonic* 21,600 in ninety days; in other words, in a distance of about 22,000 miles the *Oceanic* will steam 2,000 miles more than the *Teutonic* in nine days less time.

The New Steamship Deutschland.—The Germans have proved the efficiency of their shipyards by undertaking the construction of one of the hughest steamship of modern times. This new giant, which is in process of construction in the Vulcan shipyard at Stettin, will be called *Die Deutschland*, and will be if not the largest, the fastest steamer in the world. According to the Hamburg "Boersenblatt," this floating palace, which is now so well advanced that she will be launched in six months or less, has a length of 622 feet, a beam of 67 feet and a depth of 44 feet. To form a correct idea of these dimensions, let it be recalled that the *Pennsylvania*, of the Hamburg-American Line, was the largest steamship in the world at the time of her completion, having a length of 560 feet; yet the *Deutschland* exceeds her in length by 62 feet. With her bunkers and ballast tanks filled, the *Deutschland* will draw 29 feet of water. Her coal bunkers will have a capacity of 5,000 tons. She will be provided with two six-cylinder, quadruple-expansion engines, whose aggregate capacity will be 33,000 indicated horse power. It is difficult to comprehend this enormous power. The steamer *Prince Bismarck* has 16,500 horse power, and the steamers *Pennsylvania* and *Pretoria* have only 5,500 horse power each, with which they attain a speed of 13 or 14 knots. Thus the *Deutschland* will have twice the engine power of the *Prince Bismarck*, and six times that of the *Pennsylvania*. Twelve double boilers, each with eight furnaces, and four single boilers, each with four furnaces, will be provided to furnish the steam for the mighty engines, so that there will be 112 fires in all in the stoke hold. The steam pressure is to be

210 pounds, and the contract calls for an average speed of 23 knots per hour, although it is expected that 25 knots may be attained as a record performance. Five dynamos will be used to run the electric lights. Twenty-six life-boats will be provided —eighteen of steel, two of wood, and the remaining six will be of the collapsible type.

A better idea of the size and power of the *Deutschland* may be had, perhaps, by comparing her with the *City of New York*, whose engines develop some 18,000 or 20,000 horse power, or about 60 per cent. of that developed in the *Deutschland*. "It is a very easy matter to talk of 18,000 or 20,000 horse power," says an article in the "Locomotive" for March, 1889; "but few persons, we think, realize what it means. Assuming that the engines will require 18 pounds of steam per horse power per hour, then 160 tons of feed water must be pumped into the boilers every hour, and 160 tons of steam will pass through the engines in the same time. In twenty-four hours the feed water will amount to 3,840 tons. A tank cubical measuring 52 feet on the side would hold one day's consumption; or it would fill a length of 493 feet of a canal 40 feet wide and 7 feet deep. Taking the condensing water at thirty times the feed water, it will amount for a six days' run across the Atlantic, to not less than 691,200 tons. This would fill a cubical tank 295 feet on the side—a tank into which the biggest church in New York, steeple and all, could be put and covered up. The coal consumed will be 400 tons per day. This will require, for its combustion, 8,600 tons of air, occupying a space of 220,000,000 cubic feet. It is impossible for the mind to take in the significance of these latter figures. It may help if we say that if this air were supplied to the ship through a pipe 20 feet in diameter, the air would traverse the pipe at the rate of about 5.6 miles per hour." If the figures here given are all increased by about 70 per cent., some conception may be had of the vast quantities of water and coal and air that must be handled every time the new *Deutschland* crosses the Atlantic.—"Marine Record."

Great Lakes Freight Steamer C. A. Black.—The Detroit steamer *Clarence A. Black* is regarded as one of the most econ-

omical freight carriers in this country. This vessel, built by the Cleveland Shipbuilding Company, and fitted with the Howden system of hot draft, through arrangement with the Dry Dock Engine Works of Detroit, is credited in two elaborate reports of tests with having shown a fuel consumption of a little less than $1\frac{1}{2}$ pounds of coal per indicated horse power per hour. The *Black* is a vessel of the ordinary coarse-freight type in general use on the great lakes, and is of 6,800 net tons capacity. She is 414 feet over all, 50 feet beam, 28 feet depth. Her load of 6,800 net tons is carried on about 17 feet draught. Engines are of triple-expansion type, with cylinders of 22, 35 and 58 inches diameter and 40 inches stroke; air pump, 32 inches diameter and 14 inches stroke. She has two Scotch boilers of 13 feet 2 inches diameter and 12 feet length over all, allowed 165 pounds working pressure; four furnaces, 48 inches inside diameter, with grates of 5 feet 6 inches = 88 square feet; total heating surface, 4,292 square feet; propeller, sectional, four bladed, 13 feet 6 inches diameter and 14 feet pitch.

Particulars of a trial of this vessel, showing a consumption of only 1.46 pounds of coal per I.H.P. per hour, are as follows: Steam pressure, 165 pounds; vacuum, 22 inches; average revolutions, 87.7; indicated horse power, H.P. cylinder, 482.3; I.P. cylinder, 538.5; L.P. cylinder, 505.8; total average, 1,526.6; ref. M.E.P. to L.P. cylinder, 32.7; ratio of horse power to grate surface, 17.3; ratio of heating surface to horse power, 2.8; duration of test, 6 hours 2 minutes; total coal burned, 13,440 pounds; coal per hour, 2,228 pounds; coal per hour per I.H.P., 1.46 pounds; coal per hour per square foot of grate surface, 25.32; air pressure at fan, $1\frac{1}{8}$ pounds; temperature at hot well, 139 degrees; temperature of feed water after leaving heater, 175 degrees; speed of vessel, 12.23 miles; speed of propeller, 13.95 miles; slip of propeller, 23.3 per cent.

Ocean Records in 1898.—The honors of the past year for fast steaming across the Atlantic again go to the North German Lloyd steamer *Kaiser Wilhelm der Grosse*, which has improved upon her record of November, 1897, and on the Southampton-New York route is unapproached. She has also contrived to beat

the *Lucania's* best for a day's run, and may, therefore, be regarded as the fastest merchant vessel afloat. It can, of course, be no particular gratification to us, says a correspondent in the "Times," to contemplate this situation and to be compelled to admit that a vessel of exclusively German construction has beaten the best that we have hitherto produced. There is consolation, however, in the prospect that the *Kaiser Wilhelm der Grosse* will not retain the honor long. The new *Oceanic* of the White Star Line is to be launched on January 14 at Belfast. Her length is 704 feet over all, or 13 feet longer than was the *Great Eastern*, and her gross tonnage is over 17,000. In some respects she marks a great departure in steamships, and though her owners strongly depreciate all ambition to produce a vessel which shall be remarkable first and last for steaming power, it is well recognized that this point has been kept well to the front, and all we have been told of her fully justifies the expectation that she will prove to be the newest sovereign of the seas. Meanwhile, we may return to the *Kaiser Wilhelm der Grosse*, whose performances during the current year are shown in the following tables, compiled from abstracts of the ship's logs:

WESTWARD.

Date.	Passage.			Distance.	Average. speed.
	d.	*h.*	*m.*	*Knots.*	*Knots.*
March	5	23	37	3,100	21.59
March 30	5	20	0	3,120	22.29
April 27	6	3	57	3,115	21.06
May 25	5	21	48	3,130	22.07
June 24	6	2	43	3,123	21.36
August 3	6	2	10	3,050	20.87
September 28	6	2	38	3,052	20.81
November 2	6	5	27	3,050	20.41
EASTWARD.					
March 16	5	19	30	3,027	21.77
April 12	5	23	2	3,035	21.22
May 10	5	16	48	3,035	22.19
June 7	6	19	20	3,190	19.53
July 5	5	19	45	3,146	22.51
August 16	5	23	30	3,075	21.43
October 11	6	6	27	3,080	20.47
November 15	5	20	20	3,077	21.92

It may be remembered that the best of the three outward runs of the *Kaiser Wilhelm* in 1897, was the first, when she steamed to New York in 5 days 22 hours 30 minutes, giving an average speed of 21.39 knots. The best of the three eastbound runs, excluding the first, which was to Plymouth instead of to Southampton, was the 5 days 17 hours 8 minutes of November, an average of 22.35 knots. A glance at the table will show that during the present year both these times have been reduced. The record day's run outwards of the *Lucania* is 562 knots and homewards, 526 knots; while the *Campania's* best stands at 553 knots outwards and 528 knots homewards. These achievements have not been surpassed during 1898 by either of the Cunard vessels. Appended are details of the best passages of the leading vessels of the two lines:

CUNARD LINE.

—	Out.			Average speed.	Home.			Average speed.
	d.	*h.*	*m.*	*Knots.*	*d.*	*h.*	*m.*	*Knots.*
Lucania	5	10	37	21.30	5	11	54	21.99
Campania	5	11	13	21.21	5	13	46	20.96
Etruria	5	20	55	19.74	6	2	37	19.13
Umbria	6	3	32	18.88	6	6	46	18.59
WHITE STAR LINE.								
Majestic	6	0	5	19.65	6	2	57	19.37
Teutonic	5	23	42	19.90	5	23	44	19.60
Germanic	7	3	38	16.61	6	23	14	16.77

Apart from the bringing of Egypt to within four days of London, the Peninsular and Oriental Company has to report no special passages this past year. The two express steamers *Isis* and *Osiris*, each of 1,728 tons gross register and of 6,500 horse power, are now at work in the mail service between Brindisi and Port Said. They perform the voyage in about 48 to 50 hours, and enable those passengers who leave London at 9 P. M., on Fridays by the "P. and O. Brindisi Express" to reach Port Said on the following Tuesday night. The fastest trip yet made was by the *Osiris* in 47 hours, which represents an average speed of 20 knots —probably the greatest speed ever maintained for so long a period

by any merchant vessel of corresponding size. These express boats transfer the mails at Port Said to the large passenger steamers, which now make Marseilles their regular port of call instead of Brindisi. The old P. and O. records have to be again carried forward, as it were, for the current year, and it may be of interest if they are repeated here: Mails to Bombay in 12 days 10¾ hours by the *Caledonia*; from Bombay in 12 days 2 hours by the same vessel; to Hong Kong in 24 days by the *Australia* and the *Oriental*; to Western Australia in 23 days 11½ hours by the *Himalaya*, and to Melbourne 34 days 20 hours by the *Victoria*.

On the Cape Town route good, steady work has been accomplished by the steamers of the two leading lines. The fastest passages of the Union Company's vessels between Southampton and Cape Town, and *vice versa*, are shown in the following table:

Steamer.	Outward voyage.		Homeward voyage.	
	d.	*h.*	*d.*	*h.*
Briton	16	0	15	6
Mexican	17	0	16	19
Moor	17	12	16	9
Norman	16	5	15	9
Scot	16	4	15	8

The Castle Line records are as follows:

Steamer.	Outward voyage.			Homeward voyage.		
	d.	*h.*	*m.*	*d.*	*h.*	*m.*
Dunottar Castle	15	17	50	15	4	30
Dunvegan Castle	16	0	6	15	9	30
Tantallon Castle	16	5	54	15	14	49
Carisbrook Castle	16	11	0	15	1	11

It will be seen that the *Dunottar Castle* is the best steamer of the year on the outward and the *Carisboook Castle* on the homeward run.

Turkistan.—This steel screw steamer left the port of the Hartle pools for its trial trip on December 5. The vessel has been built by Messrs. Wm. Gray and Co., Limited, for Messrs. Frank

C. Strick and Co., Limited, of Swansea and London, the principal dimensions being: Length over all, 362 feet; extreme breadth 45 feet; depth, 25 feet 8 inches, and is of the spar-deck type, with poop, bridge and forcastle. The machinery has been constructed at the Central Marine Engine Works of Messrs. Wm. Gray and Co., Limited, and is of the triple-expansion type, with cylinders 28 inches, 43½ inches and 72 inches in diameter, and a piston stroke of 48 inches. The boilers are two in number, and are fitted with Messrs. Jas. Howden and Co.'s system of forced draft. A speed of 15 knots was easily maintained, the engines developing over 2,500 H.P., and the boilers keeping perfectly tight and furnishing a plentiful supply of steam.

Noraumore.—This turret-deck steamer, built by Messrs. Wm. Doxford & Sons, Ltd., Sunderland, to the order of the Belgian Maritime Trading Company, Antwerp, proceeded on its trial trip on December 19th. The principal dimensions are: Length, 420 feet; breadth, 50 feet; depth, 32 feet 6 inches. A speed of twelve knots was attained. Both hull and machinery have been constructed to the highest class of the British corporation.

Ultonia.—This screw steamer, which has been built for the Cunard Steamship Co., Ltd., by Messrs. C. S. Swan and Hunter, Ltd., was taken out to sea on October 28, for the trial trip. This is the largest steamer that has been built on the Northeast coast, or, in fact, in England, and is of the following leading dimensions: Length over all, 513 feet; breadth, extreme, 57 feet 4 inches; and depth, molded, 37 feet. Above the upper deck is a shelter deck extending the whole length of the vessel, and which is fitted up for carrying cattle, with fittings of the latest type. At the fore end of the vessel on this deck, accommodation is provided for the crew and firemen, and at the other end for a large number of cattlemen. Above the shelter deck is a long bridge extending out to the full width of the vessel, and which, like the shelter deck, is fitted up for the carriage of cattle, of which, on the two decks, she will carry 800 head. Above the bridge, in a large house round the engine and boiler casings, are situated the saloon and rooms for officers, petty officers, engineers, foremen cattlemen, etc. Over this house is a house

containing the master's room, chart room, and wheel house, and over all the navigating bridge. Three large refrigerating engines, made by the Liverpool Refrigeration Co., have been fitted at the forward end of the bridge, the whole of the lower 'tween deck forward being insulated for the carriage of chilled beef, bacon, etc. The engines have been built by Sir Christopher Furness, Westgarth & Co., Ltd., Middlesbrough, and drive twin screws. Each engine is of the triple-expansion type, and has cylinders 23½ inches, 38½ inches and 66 inches diameter, with a stroke of 48 inches, steam being supplied by five large single-ended boilers working at a pressure of 200 pounds per square inch, and fitted with Howden's system of forced draft.

YACHTS.

The Steam Yacht Ellide.—The steam yacht *Ellide* designed by C. D. Mosher for E. Burgess Warren, of Philadelphia, has shown on trial such an unprecedented speed that a description of the boat and machinery and of her trials should be of great interest to all who are concerned with the advance of marine construction, and especially with the development of the highest attainable speeds on the minimum size and weight.

The *Ellide* is 80 feet long, 8 feet 4 inches maximum beam, and, aside from the propeller, has a draught of about 2 feet. The normal displacement is about 13 tons. The boat is of composite construction, and is subdivided by five steel bulkheads into six water-tight compartments. The planking is of double-skin mahogany, and all the fastenings are Tobin bronze bolts.

There is one Mosher patent quadruple-expansion engine with cylinders 9 inches, 13 inches, 18 inches and 24 inches diameter by 10 inches stroke. All cylinders are fitted with piston valves, and have relief valves on both upper and lower heads. The steam chests are fitted with automatic by-pass valves. None of the cylinders have steam jackets, but all are properly lagged with magnesia and encased in polished brass.

The valves are worked by an independent valve crank shaft parallel to the main shaft, and so geared to it by double helical gears as to make an equal number of revolutions with the main shaft. Reversing is accomplished in the usual way by a spiral sleeve actuated by a reverse lever at the forward end of the engine.

All the material used in the construction of the engine is of the highest class. The main parts of the engine are of steel forgings, oil tempered and bored out hollow, and all the usual fittings are supplied in accordance with advanced engineering practice.

The propeller is 40 inches in diameter, and of about 60 inches mean pitch.

In addition to the main propelling engine there is an inboard surface condenser, and six especially-designed auxiliaries, including feed pumps, air pumps, circulating pump, bilge pump and blower. The latter supplies air to the furnaces on the closed ash pit system.

The boiler is of the Mosher water-tube type, encased in polished brass. It consists of two steam drums placed over two water drums and connected together by a number of solid-drawn steel tubes, so arranged that the gases pass twice the length of the boiler at right angles to the tubes before entering the stack, thus a high proportion of the heat liberated is absorbed, giving to the boiler a high efficiency. Each side of the boiler is practically independent, although the furnace is common to both.

The boiler has 1,203 square feet of heating surface and 30 square feet of grate surface, and is similar to those now in use in nine of the torpedo-boats of the U. S. Navy.

The trials were carried out over the statute-mile course of 5,280 feet, recently laid off by the U. S. Coast Survey steamer *A. D. Bache*, on a straight line, off Irvington-on-Hudson. The ends of the course were marked by range poles on the river bank at right angles to the course. On each run the speed of the boat was adjusted by the throttle valve, and the steam pressure maintained as nearly uniform as possible. The judges in the forward cockpit took the time with stop watches, and by a single stroke of the bell at the beginning of the mile, signaled the engine room, where indicator cards were taken, and the steam pressure and revolutions were recorded. On each of the runs over the course indicator cards were taken from each of the cylinders, and the revolutions were taken by a special speed indicator connected to the shaft of the engine. The indicators used were specially designed by Mr. Mosher for extreme high speeds, and were made under his direction by the Crosby Steam Gage Company.

Owing to the form of the boat, the entrance lines become finer and finer as the bow continues to rise out of water, while, due to the breadth and form at the stern, there is no settling or squatting at any speed. It further follows that as the bow rises the run or

buttock lines continue to become more nearly horizontal, so that at the highest speeds the after body is in large part simply sliding along nearly parallel to the surface of the water.

The highest number of revolutions on any one run was 822 per minute, but at this speed indicator cards were not secured for all cylinders.

Professor W. C. Durand, in an interesting paper in "Marine Engineering" of December, discussed the results, and it is from that article these extracts are made.

Trial Speeds Obtained.

Revolutions per minute.	Total I.H.P.	Speed, miles.
285	58.19	12.7
418	179.62	19.05
560	386.	27.3
620	542.56	31.2
748	788.93	37.
822	910.	*40.

The I.H.P. for the last run was obtained by extending the power-speed curve to the vertical ordinate through the revolution curve at 822 revolutions, checking it also by extension of revolution-speed curve.

The New Steam Yacht "Aphrodite."—The new steel ocean-cruising steam yacht *Aphrodite* was successfully launched from the shipyard of the Bath Iron Works, at Bath, Maine, on Thursday of last week. The vessel is being constructed for Col. Oliver H. Payne, of New York, who will use her for lengthy voyages. In fact, when Colonel Payne gave orders for the design of the new steam yacht, his instructions were to the effect that the vessel should be staunch enough to voyage around the world and capable of spending many days at sea. The designs were made by Charles R. Hanscomb, of the Bath Iron Works, and the entire vessel, down to the smallest detail, will be the product of this well known shipbuilding concern.

The *Aphrodite* will have the distinction of being the largest,

*40 miles corresponding to 34.73 knots.

most luxuriously appointed and speediest sea-going steam yacht ever constructed in this country. No expense is being spared in making this vessel just what the specifications insist upon, viz: the finest pleasure craft of her type afloat.

The hull of the new craft is 306 feet over all, or 263 feet between perpendiculars; 35½ feet beam, and she will draw when loaded 16 feet of water. The steel hull of the vessel is constructed in a remarkably strong and rigid manner, and her scantlings are in excess of the requirements of the rules of the American Shipmasters' Association. The yacht has a flat keel instead of the usual side-bar keel. She has moderate deadrise, an easy bilge with graceful curving sides, and the usual "tumble home." The bow lines flare above the load-water line so as to make the vessel more comfortable in a head sea. She is fitted with bilge keels or rolling chocks 24 inches deep and 140 feet long.

No permanent ballast will be necessary to insure sufficient initial stability, but four large water-ballast tanks are fitted, two forward and two aft of the machinery space, so that the displacement can be increased, and the trim, when light, regulated at will. The hull of the vessel is divided into fifteen water-tight compartments. There are no less than nine athwartship steel bulkheads, and no doors are cut in any of them except where absolutely necessary.

There are many innovations in the construction of this interesting vessel. The main deck is plated with heavy steel throughout the entire length. A top gallant forecastle deck is fitted forward with full head room between it and the main deck. The large deck house, 160 feet in length, is a steel structure of great strength and rigidity, but this metal work will soon be concealed by handsome paneled mahogany. Large round, vertical, sliding air ports are fitted in this house. These are more efficient on the ocean-going vessel, and they also tend to give a much more shipshape appearance than the rectangular windows. There is a clear deck space of about 7 feet between the rail and the deck house on each side.

It is apparently the desire of the owner to secure ample deck space and freedom at sea rather than large rooms in which to

entertain. The *Aphrodite* has a rounding stern with a medium overhang, and the stern lines of the vessel are such as warrant good behavior when running before a heavy sea. The interior arrangement of the vessel will be of the most superb character, the woodwork being handsomely carved, most of which is now in the joiner shop at the Bath Iron Works ready to go on board. The yacht is to be fitted with all the modern appliances, electric lights, two search lights, storage battery, steam windlass, etc., etc.

The engines of the *Aphrodite* will be the largest ever placed on board of a private-owned pleasure craft in this country. The cylinders are 28, 43 and 70 inches in diameter respectively, and the stroke is 38 inches. There are four massive single-ended boilers all ready to be lowered into the vessel. At natural draft these boilers will supply steam for 3,200 indicated horse power. There is no yacht afloat to-day that is fitted with machinery capable of developing this power at natural draft. The speed of the *Aphrodite* under steam alone, without forcing, will be at least fifteen knots per hour, and this she will be able to maintain on a long run, owing to her great boiler power and large coal capacity. Under forced draft she will make over seventeen knots per hour.

She is to be bark rigged, two-thirds full sail power, and will spread in all about 17,000 square feet of canvas. These sails will give steadiness in a sea-way, and in an emergency will enable her to make fair speed under canvas alone.

The *Aphrodite* has been constructed in a new, substantial steel ship house 316 feet long and 50 feet wide. Pneumatic tools have been used in her construction, and owing to the Bath Iron Works having most excellent facilities for this high class of work, they have turned out in a very short time a hull that for strength, beauty and fine workmanship is excelled by none at present afloat.

Sixteen Large Steam Yachts are in process of construction or contracted for in American shipyards, most of which are to replace yachts that were taken by the Government for naval use during the war. The largest of the lot are the new *Corsair*, now being engined and completed by the W. & A. Fletcher Co., Hoboken, for Commodore J. Pierpont Morgan, of the New York Yacht Club, which is 304 feet long over all, and the *Aphrodite*,

now being built at Bath for O. H. Payne, described above. Two of the others, however, considerably exceed 200 feet in length, the ones for Mr. Widener and Mr. J. P. Duncan, and all the remainder are much over 100 feet long—a stanch, able, sea-going fleet. There is no room for doubt that the presence of considerable of this work in American shipyards is due to the existence of the Payne yacht law, which was framed and fostered by the "Marine Journal," prohibiting foreign-built yachts from enjoying the privileges of the American flag. And without doubt orders for many more will follow.—"The Marine Journal."

Chil Howee.—The following is a description of the propelling machinery of the steam yacht *Chil Howee*, belonging to Mr. Wm. H. Evans, of Baltimore, Md.

The yacht is 126 feet long over all, 100 feet on the water line, 16 feet beam, 10½ feet deep, and 6½ feet draught. The hull is of wood, and was built by Messrs. Jos. Thomas & Son, Baltimore, Md., and the machinery by Messrs. Morton, Reed & Co., Baltimore, Md. The boilers and engines were designed by Mr. Samuel J. Williams.

The machinery space in the yacht is 22 feet 6 inches long. Three feet of this space forward of the boilers was reserved for coal bunkers. This with the two side bunkers will carry seventeen tons of coal.

There are two boilers, of the pipe or coil type, each 8 feet ½ inch long, 4 feet 4 inches wide and 7 feet high. Each boiler contains a little over 725 square feet of heating surface, and 21.6 square feet of grate surface, the furnaces being 6 feet 9 inches long and 3 feet 2 inches wide. The upper water drum is 20 inches inside diameter, 8 feet long, made of ½-inch steel, with flanged heads of ½-inch steel.

The feed-water heater consists of two narrow, box-shaped manifolds with a series of inverted U-shaped coils of pipe screwed into them. The feed water enters at one end of one of the manifolds, slowly passing up and then down through the coils into the next manifold, and from a point in that manifold, near the top, a pipe leads to one of the down-flows of the boiler, discharging the feed water at that point into the boiler.

The superheater coils are in two parts, taking steam from each end of the steam drum, then, after traversing back and forth, the steam enters a drum from which it is then taken by the main connection to the engine. The same construction applies to the other boiler.

The boilers are entirely under the deck, an iron plate flush with the deck, covering the boiler space.

There are twelve separate fresh-water tanks, six forward and six aft, under the floors, with a capacity for about 1,200 gallons fresh water.

The engines are triple expansion, with cylinders 9 inches, 14 inches, and 24 inches by 14 inches stroke. The valves are all piston valves, working in removable cages. All the valves have packing rings. The cylinders are three separate castings, placed as close together as possible, and the valve chests are on the side, the valves being operated by the Marshall valve gear. The cylinders are supported by seven straight steel columns. The base plate is of cast iron, well ribbed on the under side.

As the Marshall valve gear is used, there is but one eccentric to each engine proper, and the three eccentrics were made in the shaft forging, thus making the shaft with its three cranks and three eccentrics one solid forging. The high-pressure crank pin and bearings are $4\frac{1}{2}$ inches in diameter, and the intermediate and low-pressure crank pins and bearings are $4\frac{3}{4}$ inches in diameter. The main shaft journals are 8 inches and 10 inches long.

The dimensions of the propeller wheel are as follows:

Diameter of wheel, feet,	5.5
Pitch of wheel (true screw), feet,	8.5
Number of blades,	4
Diameter of hub, inches,	9
Length of hub, inches,	11.75
Helicoidal area, square feet,	12.97
Disk area, square feet,	23.75
Greatest width of blade (21 inches from axis), feet,	1.5
Helicoidal area divided by disk area,	.546

The thrust and propeller shaft are 4½ inches diameter, of steel, the total length being 38 feet 5 inches. The propeller is 5 feet 6 inches diameter, 8 feet 6 inches pitch, made by H. G. Trout, Buffalo, N. Y.

The surface condenser is of the Wheeler type, with 350 square feet of cooling surface, with Deane (of Holyoke) air and circulating pumps.

The boilers are fed by a Deane duplex high-pressure pump, and a Metropolitan double-tube injector. The pump and the injector are independent, and each can take its feed water from either the filter box, tanks, or from overboard. There is also provided a Deane duplex pump for pumping out the bilge, for fire purposes, and for washing decks.

As to the performance of the plant, it was found that everything worked satisfactorily, except that the engine could not be turned up to the designed speed. This was attributed to the size of the wheel, which is rather large for the engine. The highest number of revolutions made was 200. (The engineer has since stated that he has made 225 revolutions.)

At these speeds the engine turns up very smooth and free from vibration.

No accurate tests were made, but in twenty minutes from the time of lighting fires 200 pounds of steam was on the boiler, and as the engines have not been run up to their designed speed (which is 300 revolutions per minute), the boilers have not been given a severe test.

The owner reports that he ran from Cape Charles to Baltimore in 13 hours using *one* boiler, making steam easily, and the engine turning from 160 to 180 revolutions per minute.

Natural draft is used altogether, the height of stack (26 feet from the grate) giving excellent draft.

The steam is slightly superheated. The boilers show no tendency to foam or to lift the water. The circulation is very active, and all parts of the boiler keep an even temperature.

As the yacht was finished somewhat late in the season, she was taken without making any trial trips, except just enough to

see that the machinery was in order and for setting the valves.

At about 12 knots the following data were obtained:

Indicated H.P., H.P. cylinder,	99.33
Indicated H.P., I.P. cylinder,	94.75
Indicated H.P., L.P. cyiinder,	65.5
Total horse power,	259.58
Boiler pressure, by gage, pounds,	205.
First receiver, by gage, pounds,	62.5
Second receiver (gage out of order).	
Vacuum, inches,	24.
Revolutions of engine,	185.
Piston speed, feet per minute,	431.6
Diameter of piston rods, inches,	1.75

ASSOCIATION NOTES.

ANNUAL MEETING.

The eleventh annual meeting of the Society was held in the office of the Engineer-in-Chief, on the evening of the 10th of January. The meeting was of a purely business character, responses to the request in the first Association note in the November JOURNAL failing to indicate the probability of securing such papers for reading as would guarantee the desirable interest to a general meeting, if called.

The meeting was called to order at 8·35 P. M., a business quorum being present.

As no award had been made for prize essay submitted during 1898, it was so reported.

The annual report of the Secretary-Treasurer was then read, as follows:

GENTLEMEN: In accordance with the requirements of Section 14 of the By-Laws of the Society, I herewith submit the annual statement of receipts and expenditures for the twelve months ending January 7, 1899.

RECEIPTS.

Balance on hand, January 7, 1898	$5,198.59
Annual dues	1,980.20
Subscriptions, sales of JOURNALS and reprints	571.98
Advertisements	833.78
Sale of general index	8.75
Sale of society buttons	12.60
Receipts for banquet assessments, 1898	168.00
Interest on deposit	83.42
Portion of salary returned	8.50
	$8,865.82

EXPENDITURES.

Banquet, 1898	$181.65
Printing JOURNAL and reprints	2,980.50
Printing of Index for 1897, circulars, etc	77.27
Illustrations	340.55
Salary Secretary-Treasurer	900.00
Cost of society buttons	50.50
Medal for prize essay 1897 and die for same	100.00
Stationery, postage and incidentals	107.11
Purchase of back numbers of JOURNAL	53.50
	$4,791.08
Balance on hand this date, January 7, 1899	$4,074.74
	$8,865.82

A. B. WILLITS, *Secretary-Treasurer.*

The Secretary-Treasurer in calling attention to the decrease in balance on hand, stated that it was the policy of the former Secretary-Treasurer, under whose guidance these affairs were administered up to October 1 of the year in account, to purposely reduce the growing balance by giving the Society a better and larger JOURNAL. This has proved very acceptable to the Society, as there is no good reason for retaining any more than a liberal working balance on hand. It is the purpose to continue the policy of devoting the increase of income to additions to the JOURNAL.

The accounts of the Secretary-Treasurer were duly audited later and found correct.

The work of tallying the votes for the Officers for the new year was then proceeded with, and resulted in the election of the following Officers:

President, Chief Engineer Harrie Webster, U. S. Navy;

Secretary-Treasurer, Chief Engineer A. B. Willits, U. S. Navy;

Council.—Passed Assistant Engineer C. A. E. King, U. S. Navy; Passed Assistant Engineer W. W. White, U. S. Navy; Passed Assistant Engineer Emil Theiss, U. S. Navy.

There were 140 votes received by mail for the election. These were opened at this time and counted by a committee appointed for the purpose.

There was no motion made to amend the By-Laws, but the following amendment to the article governing the prize essay was adopted by unanimous vote of the members present.

"The offer by the Society governing the prize essay shall read hereafter as follows:

"The Society offers to the writer of the best original article on any engineering subject, that shall be contributed to and published in the JOURNAL during any one year, a prize of a gold medal, life membership in the Society, and a money prize of $75. The article may be contributed at any time during the year prior to November 1st, and articles not deemed by the Council to be of sufficient value to publish will be returned to the writer. Articles need not be marked as competitive, as the decision as to the best article published is to be obtained by mail slip, in the same manner and at the same time votes are obtained for election of officers (Sec. 23 of the By-Laws), and the award made at the annual meeting.

"A second prize for the second best original article contributed and published, as in the case of first-prize article, shall be $25 cash, and life membership in the Society. Decision to be obtained in the same way as above."

A vote of thanks was tendered to the President and Secretary-Treasurers, for the efficient manner in which they had conducted the work of the Society during the year.

The meeting adjourned at 9·57 P. M.

PERSONAL.

It will be no "news" to the readers of the JOURNAL to read here of the step from naval to civil life that Chief Engineer W. M. McFarland, U. S. N., our late Secretary-Treasurer, has recently taken. Through his professional and personal popularity there have been notices of this event published in most the leading technical periodicals, as well as local papers, uniformly accompanied by just such expressions of appreciation and laudation as his closer professional friends know he deserves. It is for the Navy and this Society of Naval Engineers to couple regret with their praise and congratulations, for while there is every reason to

deplore the loss of such a man to the Engineering branch of the service, the excellence of the outlook in the new field of Mr. McFarland's labor is such as to compel hearty congratulations also. He is Assistant Manager of the Westinghouse Electric and Manufacturing Company, of Pittsburg, Pa., an additional light to their establishment of no uncertain power and brilliancy.

BACK NUMBERS OF THE JOURNAL.

Frequent requests are received for particular numbers of back volumes of the JOURNAL, and as the stock in hand has become greatly reduced and broken, it is requested that those having incomplete sets and not desiring to retain them, will forward a list of the single numbers they are willing to dispose of, that opportunity may be given to others for completing their sets.

Occasionally it is possible to secure a complete set of the JOURNAL to date, and should any new member or associate desire to purchase one, the Secretary-Treasurer will be glad to extend any information he has, in reply to inquiry, in order to further the interests of those who wish to preserve these valuable and "out of print" books.

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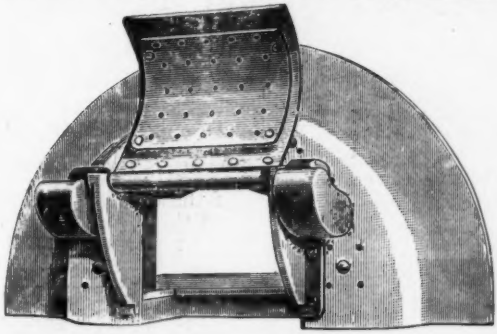

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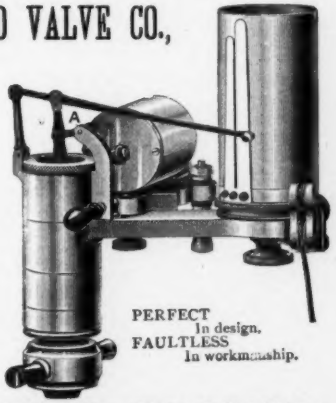

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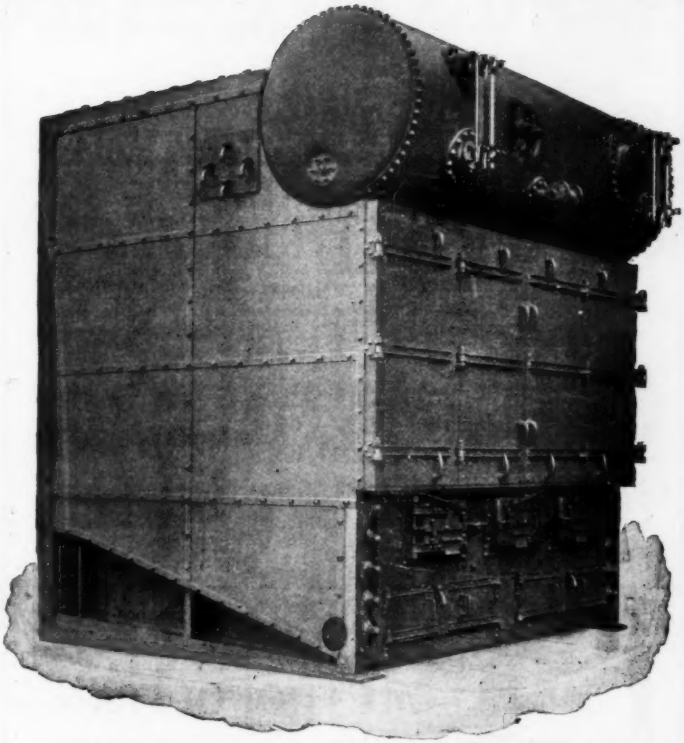

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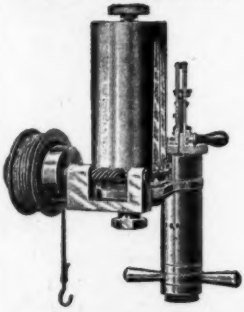

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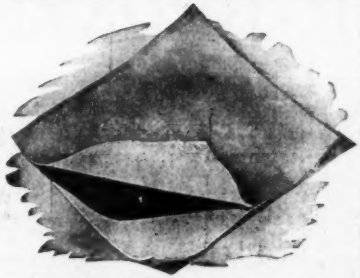

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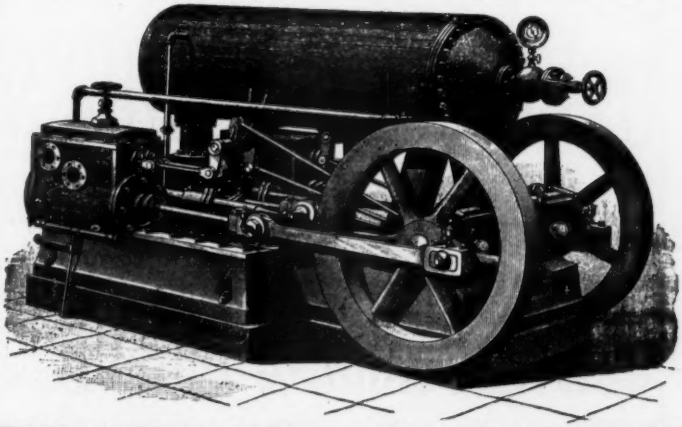

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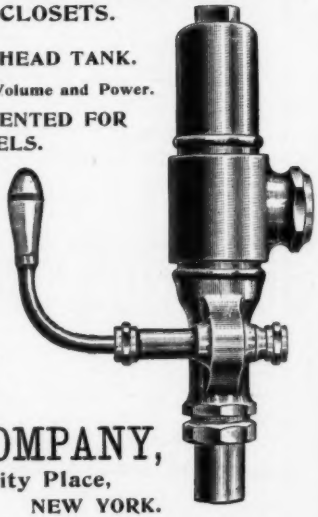

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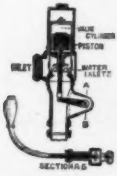

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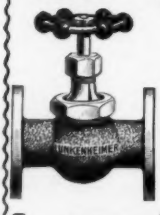

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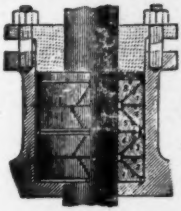

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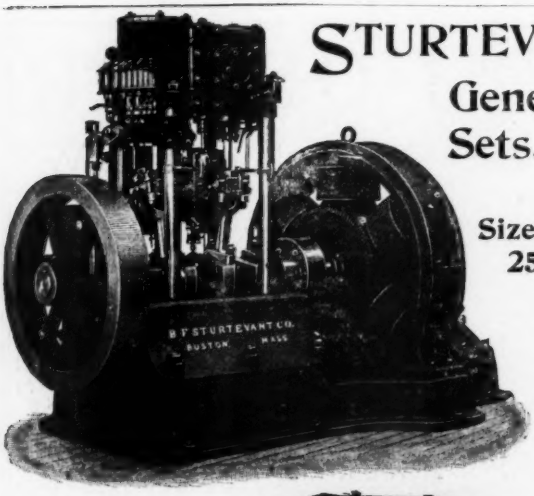

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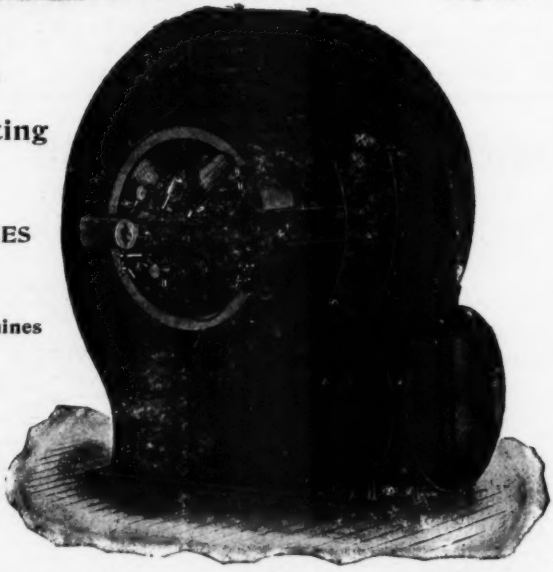

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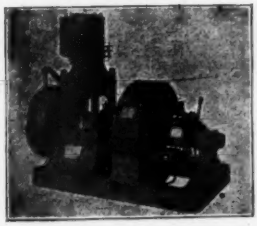

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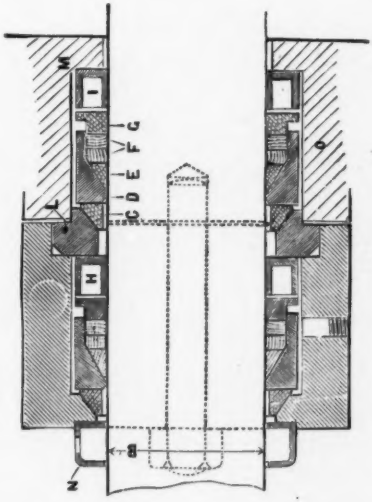

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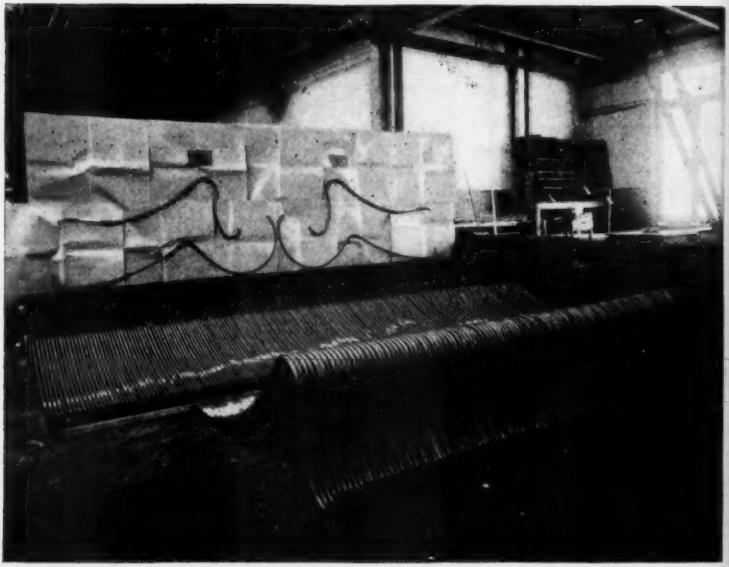

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